aerospace & advanced composites

WRK / Re Entry Chamber Facility Description

The WRK (WeltRaumKammer, German for Space Chamber), also known as Re-Entry Chamber, had been originally designed for the fast and cost-efficient characterisation of Thermal Protection System components like re-usable heat shields or ablators under the conditions of an atmospheric re-entry, limiting the testing to relevant thermal and mechanical loads but without addressing the effects of plasma chemistry.

The facility is also used for thermal vacuum testing of samples and smaller parts, including the testing of component functionality like heaters, actuators, or release mechanisms.

Technical Key Properties shall be described in this Document:

Chamber Setup

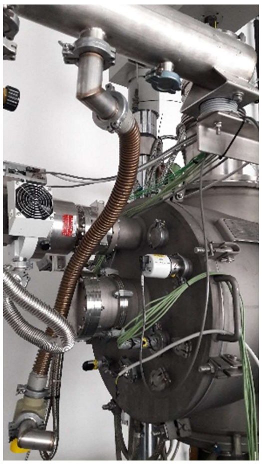
The WRK is made of a barrel-type vacuum chamber with an inner diameter of 650 mm and a depth of 600 mm. The chamber is entirely made of stainless steel and equipped with double walls for water cooling. For larger components, an extension with an inner diameter of 400 mm and a height of 500 mm allows testing of parts with a total length up to one meter.

Various feedthroughs for temperature sensors, electrical connectors, and view ports for optical measurement of temperature or strain are available.

Vacuum Generation and Control

The vacuum system consists of the following key components:

a. Vacuum Generation



Rotary Vane Pump Pfeiffer Vacuum DUO65, capable of replicating the pressure drop of the ARIANE 5 launch profile; vacuum down to ~5x10^{-3} mbar.

Turbomolecular Pump Pfeiffer Vacuum TMU521, allowing an operational pressure down to ~10^{-6} mbar, depending on actual test configuration and device under test.

b. Vacuum Measurement and Pressure Control

Typical configurations are Pfeiffer Vacuum PKR251 full-range gauge for general testing, or an APR family (APR 250/260/280) piezo sensor for tests in various gas atmospheres and at pressure down to a few mbar.

The facility can be operated at a defined vacuum pressure, ranging from the 10^{-5}mbar range to ambient pressure, under defined gas atmosphere (air, inert gas, specific gas atmosphere such as Martian atmosphere). Corrosive atmosphere is currently not feasible.

Pressure is controlled by means of a Pfeiffer Vacuum EVR 116 electronically controlled dosing valve, and a bypass line to the vacuum pumping system.

The vacuum is measured and controlled by a Pfeiffer Vacuum RVC300 controller unit.

High vacuum sensors are cleaned in regular intervals by an AAC-internal procedure and then checked against an internal reference; a calibration will only be performed on special request by customer.

Mechanical Loading System

The mechanical loading system of the WRK test facility is based on the following key components:

a. Servo-Hydraulic Testing Machine walter&bai LFA-70-S

The testing machine allows

- Maximum loads of up to70 kN
- Static or dynamic loading
  - Frequency up to 70 Hz
  - Any profile like sinusoidal, triangular, rectangular
- Mechanical and thermal loads can be run together by software control

b. Messphysik Laser Speckle Extensometer

The Laser Speckle Extensometer allows the measurement of the strain by non-contacting measurements, i.e. also when the testing is done under vacuum or specific gas atmosphere, or at high temperatures up to ~1,000°C. It is based on detecting specific patterns on the sample surface, both on the static and the dynamic end of the specimen, and their movement in the course of the tensile test. However, the method has some fundamental limitations and is less suitable for parts with very small strain-to-failure.

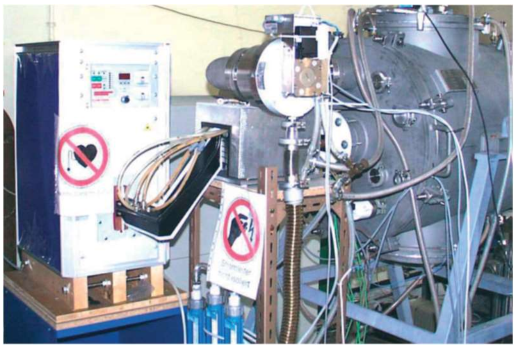
c. Standard Extensomenters

Common extensometers can be operated by means of an HBM data processing system. Up to 16 channels are feasible.

Heating / Cooling Systems

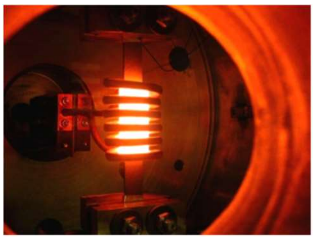
For heating of the samples, three different systems are available:

a. Inductive Heating System



For high temperatures and high heating rates, an induction-heating system PlusthermTN-30 is available. Key features are:

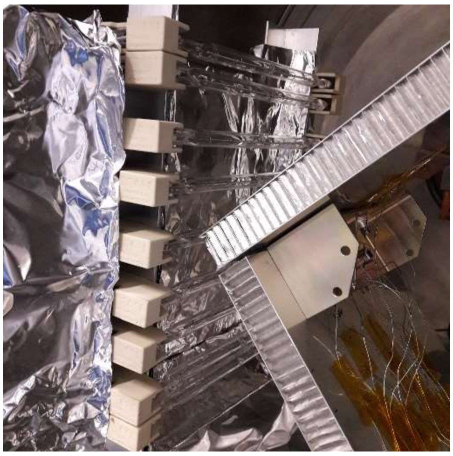
- Heating Power: 30 kW
- Automatic optimisation of operation frequency for best possible performance
- Heating Rate and maximum temperature depending on test item
  - For small metallic samples with 10 mm diameter, several 100K/second
  - CMC tensile samples – with susceptor tube – about 400 K/min
  - For powder-metallurgical investigations, 2,400 °C for some hours successfully applied



- Non-metallic and non-conductive samples require susceptor tubes for indirect heating (susceptor, e.g. graphite or ODS-Pt/Rh) heated by induction, sample heated by radiation from the susceptor
- Combination of inductive heating, mechanical loading, and laser speckle extension measurement successfully proven in various testing activities

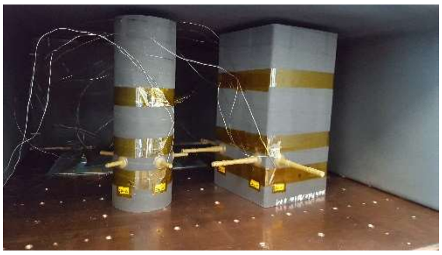
b. Radiation Heating System

Specific test environments require radiation heating. The WRK has been equipped with a highly versatile radiation heating system with the following key properties:



- Flexible system based on high performance OTS halogen radiators
- Power density: up to 100 kW/m^2
- Size and shape of heating area can be adjusted to customer specifications
- Multi-zone heating feasible, with different heat fluxes or temperature at various locations of DUT
- Testing under vacuum or under gas atmosphere feasible (not in the pressure range from ~0.05 to 5 mbar due to electric arcing)

c. Process Plate – electrically heated and LN2 cooled



This set-up is commonly used for thermal cycling or thermal vacuum bake-out. It consists of a copper-made process plate with the following key features:

- Dimensions: 500x500 mm
  - For sample fixation, equipped with a 60x50mmgrid of M6 threads
- Maximum temperature: 300 °C continuous, up to 350 °C short-term
- Minimum temperature -190 °C under vacuum, ~-180 °C under nitrogen gas
- Heating/Cooling Range up to 8 K/min
- 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
- Operation Modes:
  - Heating: Electrical, using the Eurotherm units and thyristor
  - Cooling: LN2 based, intermittent cooling by electrically operated valves

Temperature Control and Temperature Measurement

The different heating methods as described before require thorough consideration of the most appropriate temperature measurement and control. Key factors are

- Expected maximum temperature
- Position of the temperature measurement

For all test environments, the temperature control is achieved by Eurotherm PID controllers, allowing multi-step temperature programming and control:

- Eurotherm 2500P/2416 system – our standard test configuration:
  - For pyrometers, A/D signal processing in the 2500P unit and a specific software code, based on the 4-20 mA output of the pyrometers
  - For thermocouples (usually Type K), internal functionality of the units
- Additional Eurotherm 2408 or 2416 units
  - For operating multiple heating units, e.g. radiation heater, process plates
  - Synchronisation of different units by software code
- Use of pyrometer-controlled heating and thermocouple-controlled cooling (or support heating) is feasible

Some details shall be given:

a. Thermocouples

Thermocouples are the preferred method for temperatures not exceeding 1,300°C, and are the only possibility when temperatures are lower than approx. 150 °C.

- Temperature control of copper process plate and radiative heated test items:
  - Shielded Type K sensor, 1.5 mm diameter, Inconel
- Temperature measurement on most test items when expected temperature does not exceed ~600 °C (700 °C short term)
  - Shielded Type K sensor, 0.5 mm diameter, Inconel
  - Up to ~300 °C: Fixation using Kapton adhesive tape
  - Higher temperatures: Fixation by clamping, bolting, HT adhesive
- Measurement and control of higher temperatures also possible by specific types of thermocouples, though not permanently installed in test facility:
  - Up to 1,768 °C – Type S
  - Up to 1,820 °C – Type B
- The Type K thermocouples are connected to the main control computer using Datexel DAT 3018 signal converters.
- The entire control loop (sensor/converter) is regularly calibrated according to AAC´s internal QA procedures.

b. Pyrometers

For high temperature measurements, or for test configurations requiring a non-contacting measurement, various pyrometers are available. All pyrometers can be used for recording the sample temperature, or for providing the reference temperature for all heating systems available on this facility. The simultaneous use of several pyrometers is feasible. In "Control" configuration, the automated switch from a low temperature system to high temperature pyrometer is feasible by specific software codes.

The list of available pyrometers is compiled in Table 1. The measurement needs some consideration about the actual conditions:

- One-colour pyrometers – requiring thorough consideration of surface emissivity at the measurement spot and may require additional calibration steps. Furthermore, the results are strongly influenced by pyrolysis products and changes in surface emissivity, e.g. caused by sample charring
- Two-colour (quotient) pyrometers – less sensitive to sample surface emissivity and evolution of pyrolysis gases

Additional Support Equipment

- 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).
- For operating heaters, actuators, or other electrical component, several power supplies with various output power, voltage, and current are available.
- To assess the amount of material evaporated from the sample during the thermal vacuum test a TQCM (**T**emperature-controlled **Q**uartz **C**rystal **M**icrobalance) may be installed.
- For RGA analysis (**R**esidual **G**as **A**nalysis) a quadrupole mass spectrometer can be attached to the chamber.
- 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.

Table of Equipment

To summarise the information given above, Table 1 lists the equipment used at the WRK test rig. Additional equipment not exclusively used for the WRK is compiled in Table 2.

Table 1: List of equipment for WRK test rig

Equipment	Type	Ser.Nr	Remark
Rotary vane pump	Pfeiffer DUO 65	20213169	
Turbo pump	Pfeiffer TMU 521	1291057	
Vacuum Controller	Pfeiffer RVC300	PFI 00792	Controller for EVR116/APR2xx
Vacuum control valve	Pfeiffer EVR 116	44280877	Electro-mechanical dosing valve
Vacuum gauge	Pfeiffer APR 280	44205597	Piezo transducer, 1-1,300 mbar
Vacuum gauge	Pfeiffer PKR 251	44443194	Full Range Gauge (combined Pirani and cold cathode/inv. magnetron
Induction Generator	Plustherm TNX-30	866,02	With adapting transformer for small coils / high current
Pyrometer	IMPAC IGAQ10-LO	3855600/454	300-1,000; two colour pyrometer
Pyrometer	IMPAC ISQ10-LO	3855500/357	750-1,800; two colour pyrometer
Pyrometer	IMPAC ISR12-LO	3855120/1317	1,000-2,500; two colour pyrometer
Pyrometer	Infratherm IP 140	3875560/192	160-1,200
Pyrometer	Infratherm IGA 140	3875300/233	300-1,300 °C
Pyrometer	Infratherm IGA 140	3875300/234	300-1,300 °C
Temperature Controllers	Eurotherm 2500P Eurotherm 2416	SL2.509 FC1344001983	Input signal converter unit Standard PID controller
Thermocouples	16 x Type K 0.5 mm dia shielded thermocouples	n/a	Manufacturer: ICCP, Austria
Servo-Hydraulic Test Machine	Walter&bai LF-70-S	573/K11902	
Load Sensor	LF-70-S	573/K11902	Mounted in crosshead / 70 kN
Load Sensor	Burster 85041		Mounted inside vacuum chamber / 100 kN
Video Extensometer	ME-46 NG	11074171	
Laser Speckle Extensometer	ME53-33R	5220095 5240134	

Table 2: List of additional equipment not permanently used for WRK test rig

Equipment	Type	Serial Nr	Remark
Multimeter	Keithley 2700	4045974	with Keithley 7700 multiplexer
PT100 thermo-elements	OMEGA Thinfilm RTD Element F3105	n/a	Optional. Only on 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	Quadrupole PFEIFFER QMG422	44244781	RF Generator QMH 400-5 AnalyzerQMA 400
Calibration furnace	Ametek CTC-650 B RS232	620568-00905	

List of Consumables

The standard consumables are listed in Table 3 below. Other consumables may be used if agreed on between AAC and Customer.

Table 3: Permitted consumables in the WRK test rig

Consumable	Quality	Vendor / Article ID#
Cleaning fluids – General Use: • Acetone • Ethanol • 2-Propanol	technical grade technical grade 99.5%	W. Neuber's Enkel Roth Lactane VWR
Cleaning fluids – Sensitive Test Items: • 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
Cleaning Tissue: • Standard: White paper tissues • Optional: Cleanroom Wipers	OTS non-linting	Various suppliers VWR 115-0036
Mounting samples and thermo-sensors: • Kapton tape	ECSS-Q-ST-70-02C passed	RS-Components Art.-No. 436-2778
Purging / Venting: • Nitrogen (standard) • Argon (on request) • Carbon dioxide (on request)	Grade 5.0, 99.999% from Tank Grade 5.0, 99.999% Grade 3.0, 99.9%	Messer Austria
Thermal Shielding / Homogenisation: • Aluminium foil • Multi-layer isolation (T_m 150 °C)	OTS MLI Coolcat 2	Various suppliers RUAG Space Austria