IPETRONIK

AUTOMOTIVE ENGINEERING

IPEengineering Service Portfolio

CONTENT

COMPANY

Welcome to IPETRONIK!

IPETRONIK is a globally operating company for mobile measurement technologies, DAQ software, engineering services, and test bench technology for the automotive industry as well as in the aerospace and turbines sector.

Improving power, range, and comfort while minimizing costs, development times, and consumption? E-mobility, alternative drive systems, and autonomous driving present great challenges for OEMs, TIERs, and their partners.

In combining German engineering with innovative strength and a keen sense for the questions of tomorrow, we provide the ideal solution. We support you from the early vehicle development to fleet testing and the maintenance of your series. We help you realize the development of new components, from neutral benchmark to start of production. With pioneering solutions developed in-house: test benches, measurement technology, DAQ software. With concepts and services custom-tailored to your requirements. With valid data for every link of the process chain. With expertise and passion. In the field Automotive, we offer measurement and testing technology for the main areas: acoustics, acoustics simulation, thermodynamics, thermal management.

We are divided into the five business units **IPEmeasure**, **IPEmotion**, **IPEengineering**, **IPEtec** and **IPEservices**. The combination of these strategically interlocking specialist areas is so far unique on the market and enables the optimal fulfillment of demanding research, development and test requirements in automotive applications and diverse industrial applications.

FOUNDATION
1989

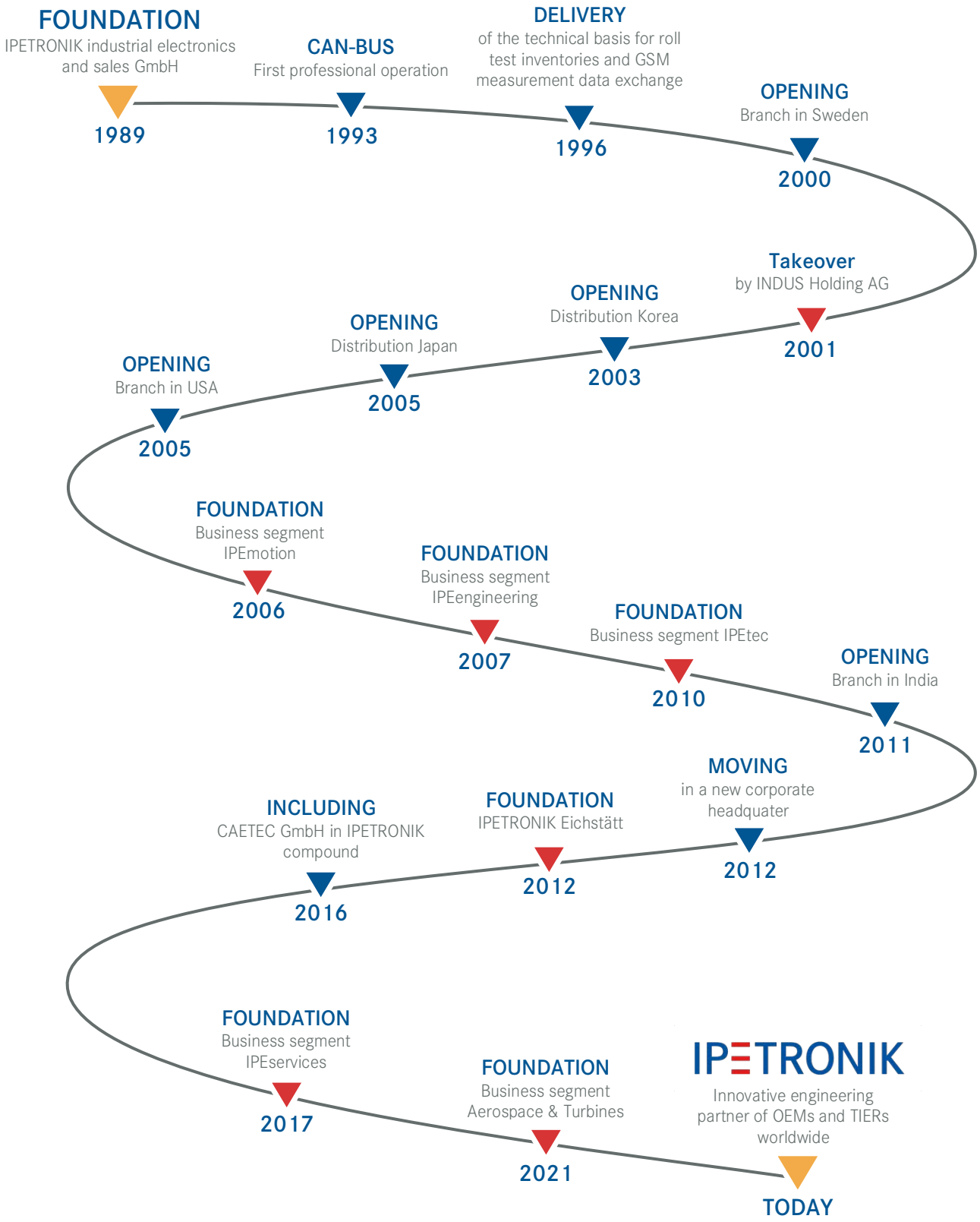
HEADQUARTERS
Baden-Baden

EMPLOYEES
300

BRANCH OFFICES
in 21 countries

100% SUBSIDIARY COMPANY
Indus Holding AG

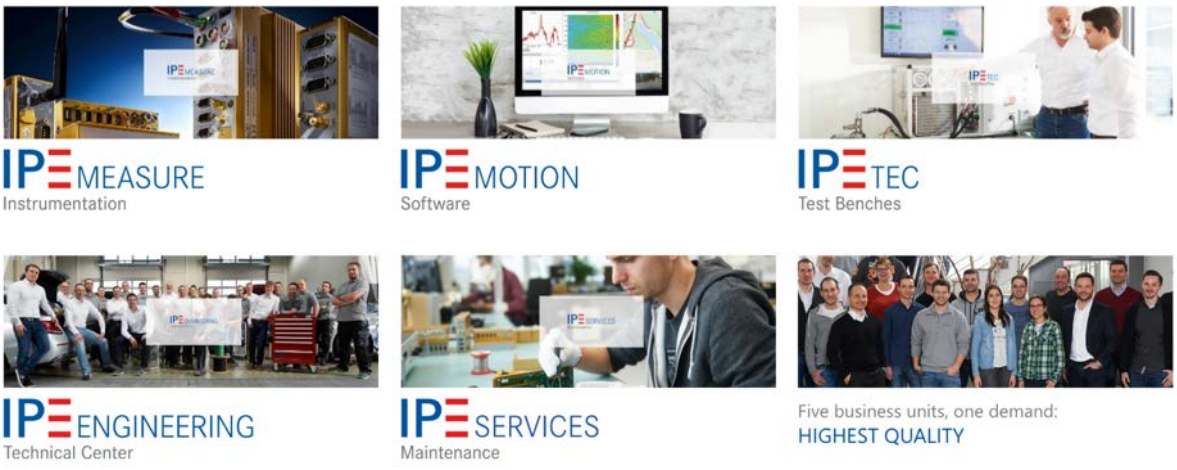
History


FOUNDATION
IPETRONIK industrial electronics and sales GmbH
1989
CAN-BUS
First professional operation
1993
DELIVERY
of the technical basis for roll test inventories and GSM measurement data exchange
1996
OPENING
Branch in Sweden
2000
Takeover
by INDUS Holding AG
2001
OPENING
Distribution Korea
2003
OPENING
Distribution Japan
2005
OPENING
Branch in USA
2005
FOUNDATION
Business segment IPEmotion
2006
FOUNDATION
Business segment IPEengineering
2007
FOUNDATION
Business segment IPEtec
2010
OPENING
Branch in India
2011
MOVING
in a new corporate headquater
2012
FOUNDATION
IPETRONIK Eichstätt
2012
INCLUDING
CAETEC GmbH in IPETRONIK compound
2016
FOUNDATION
Business segment IPEservices
2017
FOUNDATION
Business segment Aerospace & Turbines
2021
IPETRONIK
Innovative engineering partner of OEMs and TIERs worldwide
TODAY

Company locations

Examples for system integration, fleet testing and thermal management

Our five business units IPEmeasure, IPEmotion, IPEengineering, IPEtec and IPEservices combine an extensive product portfolio with a versatile range of services. Our goal is to provide integrated solutions that offer our customers added value. That is why we always have the optimal solution consisting of measurement technology, software systems and engineering competencies. The combination of our expertise in thermal management, high-volume fleet testing and engineering services for test bench solutions are unique in the market. As a system supplier, we offer all components from a single source - this makes us an important partner who creates new solutions with the customer and implements extraordinary developments.



IPEengineering business unit

Engineering services

As a specialist for vehicle and test bench testing, climate acoustics as well as thermal management, we offer the entire range of services to be able to implement the constantly growing requirements in the automotive sector quickly and efficiently. We realize complete development projects with alternative vehicle drives. In addition to the actual measurement technology, IPETRONIK's strength lies in the implementation of measurement tasks. Even more extensive projects are handled by our specialists from a single source. The range of services offered by the IPETRONIK Technology Center is diverse. This includes setting up and dismantling test vehicles and accompanying summer and winter tests. We carry out comprehensive project series including complete benchmarking with various production vehicles. This includes endurance testing, component testing, comparative analyses, statistical evaluations and the preparation of test reports.

Worldwide fleet testing and measurement data management with "IPEcloud MDM”

Our data loggers and measurement modules are used in many endurance fleet tests in the field of powertrain protection and HVAC thermal management. We not only provide our customers with the hardware, but also accompany the fleet testing and carry it out completely, including data feedback. Our work does not stop with the delivery of the measurement data: Because we offer cloud-based software infrastructures to systematically manage and evaluate large amounts of data. We also support the use of simulation tools such as MATLAB/Simulink for design models, so that we are equally well equipped for the future in this segment.

Thermal management redefined

In the context of new drive technologies, we are continuously working on further development with our system partners in the field of vehicle air conditioning and aggregate cooling. We design test rigs and system components that enable efficient development of the heart of any refrigeration system - the compressor. The latest generation of electrically driven compressors (eKMV), which find their application in electric and hybrid vehicles, were accompanied by the engineering competences from IPETRONIK - from development to series introduction. In the course of this, we also supported the development and introduction of heat pump technology in the vehicle. In this way, the range of the batteries could be significantly improved. With our highly integrated thermal management test benches (TME), we can also optimally simulate the entire air circuit as well as the energy output of electric motors and batteries.

IPEtec business unit

Thermodynamic test bench solutions

IPETRONIK is the specialist for the development and construction of test benches. Our business unit IPEtec offers all services - starting with the idea, conception and construction up to the finished test bench. High vertical range of manufacture, a fixed contact person for the complete system, short ways as well as high expertise are only some advantages we offer to the customer. Our test benches simulate thermodynamic processes for refrigeration cycle components such as compressors, heat exchangers and HVACs. Systematic and reproducible test bench testing significantly shortens development times. Whether classical mechanical engineering, refrigeration and thermodynamic process engineering or plant operation and PLC control technology - our engineers and technicians work in almost all disciplines related to the development of test benches. In addition, IPETRONIK guarantees a high degree of maturity already upon delivery, thus accelerating rapid installation and commissioning at the customer's site.

IPEmeasure business unit

Measurement technology for vehicle development

We have been supporting our customers as a reliable partner for 30 years, accompanying vehicle development on the road, in off-highway projects and on the test bench. Many leading OEM manufacturers worldwide have been successfully using IPETRONIK measurement systems for years. We develop solutions for our customers with the aim of making an optimal contribution to improving vehicle development and road testing. We create tailor-made solutions according to customer requirements. In doing so, our products and services meet the highest quality standards. Each realization takes into account the system concept and optimally integrates the specific customer requirements into the overall system. In this way, we create added value for our customers. We stand by "Made in Germany", because the design and production of our products is carried out in Germany. This enables us to ensure that the quality is right and that the systems function even in continuous use and under the harshest climatic conditions.

IPEmotion business unit

High-precision and user-friendly measurement software

Practice-oriented use of measuring equipment and reliable data acquisition are our top priorities. To this end, we have developed IPEmotion - an easy-to-use measurement software for all applications in the testing process. IPEmotion supports measurement applications in the field of automotive vehicle testing through special plug-ins - regardless of the hardware used. Likewise, the software easily combines complex ECU applications with high-precision measurement technology for physical quantities. Through customer-specific setup and adapted setup, IPEmotion becomes an individual software solution whose data display can be flexibly adapted - even during ongoing measurement and storage (online diagnosis). The measurement data acquisition software is available in several languages. It is designed for the acquisition of large amounts of data and enables automatic evaluation, report generation and offline measurement data processing.

IPEservices business unit

Customized calibration services and services

With our range of services, we create tangible added value for our customers. We are available as a contact partner throughout the entire period of use to ensure that software packages, test benches, data loggers and measurement modules are in perfect operating condition. When checking the measuring systems, we offer various gradations - depending on the customer's requirements: The entry-level offer includes a functional check, firmware updates, and calibration and adjustment at 23 °C room temperature. Another option includes calibration and adjustment over the entire temperature range, in which the modules are calibrated (via five support points) in the range from -40 °C to +85 °C. For customers who require maximum accuracy, we offer the so-called measurement chain calibration for thermocouples. In this case, the module and each sensor are calibrated individually for each channel via reference bands. All calibration data and certificates can be provided via VDI exchange format 2623 to simplify processing in customers' own test equipment databases.

We also carry out preventive maintenance and servicing work for test benches, either on site or with the aid of remote maintenance systems. In our KBA-accredited calibration laboratory, we implement leakage measurements on air conditioning systems and thus determine the refrigerant leakage from the system. We are ISO 9001 certified and our management processes create the conditions and framework for the high reliability of our products as well as for the optimal fulfillment of customer requirements.

THERMAL MANAGEMENT

Thermal management system test bench

Thermal management is a key topic in vehicle development that is taken into account in the development process right from the start. Valuable development steps can be taken at an early stage on a thermal management system test bench. By integrating calculation models and simulators/emulators, qualitative statements on systems, components and control strategies for cooling, heating and refrigeration circuits could be made at an early stage of development (without the vehicle). In addition, early testing of operating strategies is possible. In further phases of development (including series production support), problems can be reproduced and causes investigated in a reproducible environment.

IPETRONIK services with the thermal management system test bench

- Dynamic load cases on the thermal management system test bench and sharpening of simulations
- Function and control development on thermal management
- HIL with vehicle control unit and real cooling and refrigerant circuits
- Innovative heat pump refrigeration cycles and concepts – analysis and optimization
- Characteristic diagrams for coolant circuit control – Curve diagrams for actuator control
- Refrigerant circuit system optimization – basic investigations and system adjustment
- Investigation of system instability/assessment of critical load cases
- Investigation regarding refrigerant displacements in the system
- Safeguarding investigations of component requirements within the overall system
- Oil circulation ratio hedges/oil fill rate surveys and recommendations.
- Standard measuring programs for safeguarding e.g. SAE matrix, LCCP etc.
- Refrigerant charge determinations
- Investigation of unexpected problems in series circuits – finding causes and solutions

Technical data

4 air conditioning modules - specifications vary depending on the module	
Air volume flows	up to 8000 m³/h
Temperature range	-20 ... 60 °C
Humidity range (+10 to 60°C)	15 % - 85 % (dew point range relevant)
Heating capacity	33 kW
Cooling capacity	30 kW
Water-glycol circuit emulators - modules available in different power ranges	
Volume flow	0 ... 30 l/min
Pressure loss	30 ... 1000 mbar
Heating capacity	30 kW
Cooling capacity	11 kW
DC power supplies (HV + LV)	
Voltage range	5 ... 1000 V
Power	30 kW

Application examples

Dynamic load cases on the thermal management system test bench

Relevant test sequences for testing refrigeration and cooling circuits, system architecture and functionality as well as performance in an early development phase; feedback to simulation models

Project Objective:

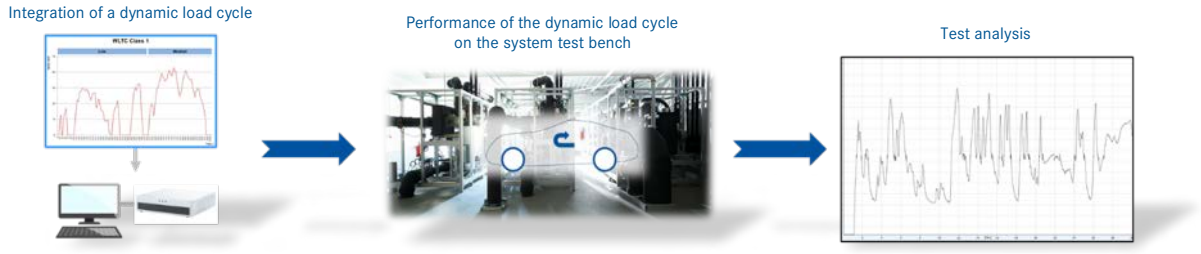
Mapping of dynamic load cases (e.g. WLTP cycle) on the system test bench for analysis and optimization of system behavior

Implementation:

Integration of dynamic load cases (sequence scripts); automated control of vehicle actuators/test stand peripherals; emulation of missing vehicle aggregates

Result:

Results on the dynamic system behavior of the development status, such as thermal influence of the heat flows from the battery and e-machine on the cooling circuit (system heating curve)



Function and control development on thermal management (preliminary development)

E.g. operating mode development, validation, function development and description, control development in cooperation with customers and partners

Project Objective:

Development of a pre-development software for the regulation/control of an indirect heat pump system with natural refrigerant and active battery cooling.

Implementation:

- Develop functional description based on the system circuits
- Define relevant sensors and actuators for closed-loop/open-loop control
- Conversion of the function description in MATLAB Simulink with initial operation
- Commissioning of the control model on the thermal management system test bench
- Validation and parameterization of the software (application)
- Elaborate comprehensive documentation

Result:

Control model, documentation, user interface for real-time ECU

HIL with vehicle control unit and real cooling and refrigerant circuits

With our customers and partners: Control of test objects on the thermal management system test bench via vehicle ECU/ECU

Project Objective:

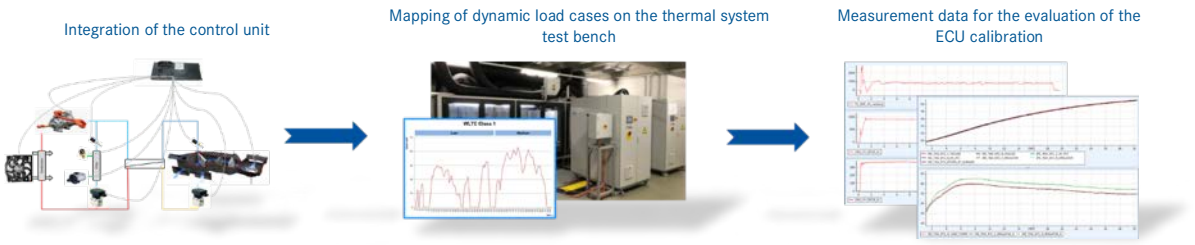
Control/integration of the vehicle actuators and sensors installed in the test bench by means of a vehicle control unit for validation of the control unit software/information

Implementation:

- Hardware/software integration into the thermal management system test bench
- Control of vehicle actuators (e.g. air conditioning compressor, pumps, valves) via ECU
- Control of the test bench by means of model environment
- Mapping of a dynamic load case
- Analysis

Result:

Developed pre-development software and documentation on system behavior and thermal management in interaction with the ECU.



Innovative heat pump refrigeration cycles & concepts – analysis and optimization

E.g. investigation and evaluation of novel, innovative components within the system refrigerant circuit with heat pump function. Analysis of technically relevant variables such as heat flows, efficiency and pressure loss criteria.

Project Objective:

Performance and Efficiency Analysis of an Innovative Refrigerant Cycle Compared to a Base System

Implementation:

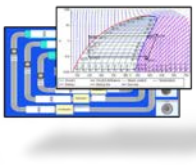
- Vehicle realistic design of a basic refrigerant circuit
- Execution and evaluation of basic measurements
- Conversion to innovative alternative concept/component adaptation by prototype store
- Carrying out comparative measurement series
- Analysis of performance, efficiency and other system variables

Result:

Meaningful results and optimization potentials via pre-development concept of the customer

Implementation of the pre-development concept on the system test bench

Measurement on the thermal management system test bench



Result Analysis

Characteristic diagrams for coolant circuit control - Curve diagrams for actuators for closed-loop control

Measurement of cooling circuit pumps, valves and combinations within the water-glycol circuits for the creation of characteristic diagrams for the control of the actuators in the systems

Project Objective:

Generation of flow maps for components in the glycol-water circuit (pumps, switching valves) of a vehicle system

Implementation:

- System structure analogous to vehicle package
- DUT commissioning
- Customized measurement program on the thermal management system test bench
- Evaluation

Result:

Drive System-specific map as control basis for vehicle control unit calibration

Refrigerant circuit system optimization - basic investigations and system adjustment

E.g. pressure loss investigation and optimization, investigation of component dimensioning, high pressure protection.

Investigation of system instability/assessment of critical load cases

E.g. investigation of system stability within different operating modes/environmental conditions (high pressure, hot gas temperature, minimum cooling requirements, "bounce" during operation, etc.).

Investigation regarding refrigerant displacements in the system

Analysis of typical problems as well as critical operating and quiescent conditions in WP/AC refrigerant circuits.

Safeguarding investigations of component requirements within the overall system

Investigation of component behavior within a system with regard to performance, efficiency and pressure drop

Oil circulation ratio hedges/oil fill rate surveys and recommendations.

Determination/recommendation of an oil fill rate, oil retention in the compressor, OCR rate for a variety of load cases.

Standard measuring programs for safeguarding e.g. SAE matrix, LCCP etc.

Test programs consisting of stationary operating points with defined boundary conditions e.g. for evaluation/comparability of performance/efficiency of the refrigerant circuit.

Refrigerant charge determinations

Ideal refrigerant charge levels with commercially available as well as novel refrigerants for vehicle circuits and test bench setups, overcharge and undercharge testing, system robustness, etc.

Investigation of unexpected problems in series circuits - finding causes and solutions

Targeted and rapid readjustment and analysis of thermal management challenges

System test bench

In the age of e-mobility, the refrigerant circuit serves not only to provide comfort air conditioning for the passenger cabin, but also to cool the electric drive train and the battery. It thus becomes one of the central subsystems of the vehicle and must be taken into account from the very beginning of development. Since neither vehicles nor subsystems are usually available at this early stage, the ducts, evaporators and other heat exchangers are built geodesically. The powertrain and battery are represented by emulators, and conditioned air is applied to the indoor evaporators. The air path for the condenser simulates temperature and driving speed. This allows caloric (performance) evaluation of the system, testing of different interconnections, comparison of different components, and development of operating strategies.

IPETRONIK services with the system test bench

- LCCP/SAE matrix
- Filling quantity determination
- COP (system, heat pumps, HWT)
- Oil circulation rate
- Refrigerant mass flow
- System and component performance measurements (KM/air/water/current)
- Measurement of valves (EXV/TXV)
- Measurement of condensers (air/water)
- Measurement of evaporators (superheat, spread, latent and sensible power)
- Compressor measurement
- Measurement of plate transducers
- Determine operating strategy
- Comparison of different system architectures
- Endurance run
- Liquid startup
- Liquid slugging
- Noise emissions from refrigerant circuit components in HVAC

Technical data

3 Clearances - specifications vary depending on the air distance	
Air volume flows	up to 4000 m³/h
Temperature range	-20°C ... +60°C
Humidity range (+10 to 60°C)	7 % ... 95 % (depending on dew point)
Heating capacity	10 kW
Cooling capacity	18 kW
2 cooling water emulators	
Volume flow	30 l/h
Pressure loss	30 ... 1000 mbar
Heating capacity	18 kW
Cooling capacity	11 kW
DC power supplies (HV + LV)	
Voltage range	0 ... 1000 V
Power	0 ... 10 kW
1 Drive with torque measuring shaft for mechanical compressors	
Speed	0 ... 9000 1/min
Power	0 ... 10 kW

Application examples

LCCP- Matrix

LCCP (Life Cycle Climate Performance) is a test specification that can be used to evaluate air conditioning systems in terms of their impact on global warming over their entire life cycle.

Project Objective:

Determining the COP at a given power

SAE matrix

SAE (Society of Automotive Engineers) describe standardized tests for efficiency and performance. This makes it easier to compare air-conditioning systems with one another.

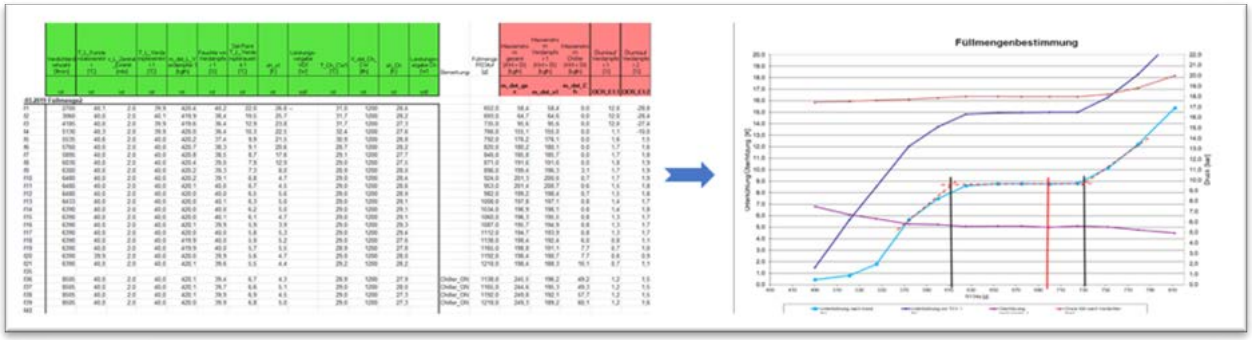
Filling quantity determinations

Project Objective:

Determination of ideal refrigerant charge levels (charge level in the receiver) with commercially available as well as novel refrigerants for vehicle circuits and test bench setups, overcharge and undercharge investigations, system robustness, determination of variables for undercharge detection, etc.

Result:

As a result diagram, the most important parameter is subcooling by condenser assembly (consists of condenser, receiver and subcooler), which can be used to determine the filling level of the receiver.



COP (system, heat pumps, HWT)

Determination of efficiency and delivery rates (COP: Coefficient Of Performance) of systems and individual components. Here, performance is measured and set in relation to each other.

Examples:

$$COP_{System} = \frac{\dot{q}_o}{P_{\text{Drive}}} \qquad COP_{HWT-Net} = \frac{\dot{q}_{HWT}}{P_{Drive} + P_{PTC}} \qquad COP_{\text{Heat pump}} = \frac{\dot{q}_{Transformer}}{P_{\text{Drive}}}$$

Oil circulation rate

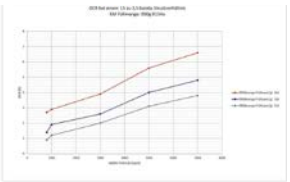
Measurement of oil circulation rates (OCR) under different operating conditions. This allows problems such as insufficient lubrication and oil displacement to be detected. Furthermore, the OCR flows into the refrigerant-side balance. We can measure most common oil-refrigerant mixtures.

By measuring sonic velocity, pressure and temperature, the oil circulation rate can be calculated via a quadric and a suitable parameter set.

Measurement matrix (e.g. SAE matrix)

Measurement performance on the system test bench incl. OCR measurement technology

OCR (%) Curve share



Refrigerant mass flow

By means of Coriolis meters, measuring turbines or oval wheel meters, refrigerant mass flows can be measured. This is necessary to calculate the refrigerant side cooling capacity.

System and component performance measurements (KM/air/water/current)

Ultrasonic sensors and differential pressure sensors, such as Venturi tubes, can be used to measure air volume flows, from which the air mass flow is calculated using pressure, temperature and humidity. Together with humidity sensors upstream and downstream of the evaporators, the cooling capacities on the air side are determined and compared with those on the refrigerant side. Static mixers are used to determine cooling water side performance to prevent temperature stratification. With our highly accurate measurement technology, electrical power consumptions of compressors can be determined precisely.

Measurement of valves (EXV/TXV)

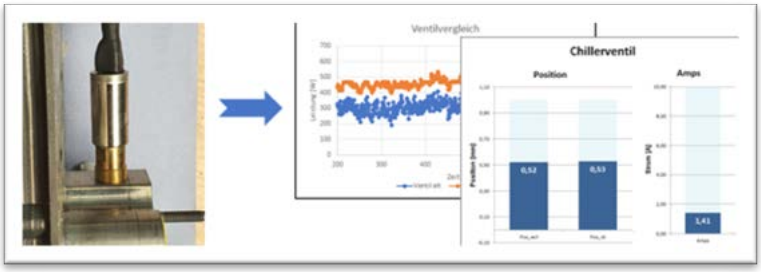
Test of a new type of EXV, which has no stepper motor and would therefore be much cheaper. Here it was the EXV for the chiller. Control quality and performance were to be evaluated.

Project Objective:

Installation and control of the valve; passing through various measuring points for comparison with the results of a stepper motor valve.

Result:

Comparison of thermodynamically relevant variables



Measurement of condensers (air/water)

Due to a failure of the air conditioning system, a conspicuous temperature distribution on the condenser surface (air-cooled) was detected in a service center of the customer. The temperature difference between the port side and the receiver side was unusually high. The objective of the investigation was to confirm this distribution, determine the cause, and propose solutions. Test performed:

Project Objective:

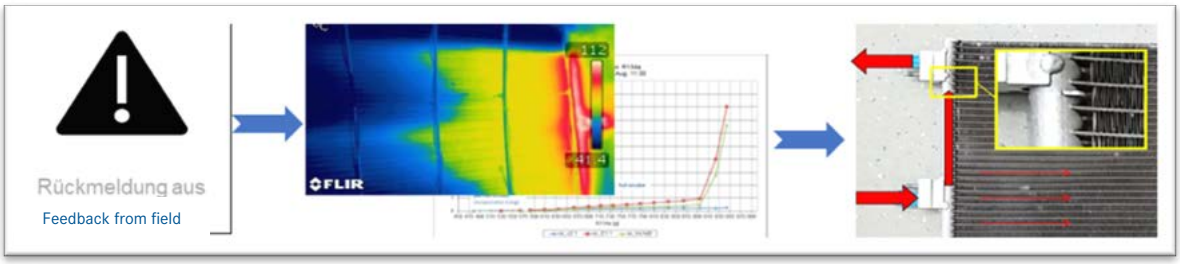
Review field observations and analyze root causes; review samples from serial production of condenser assemblies.

Implementation:

Performing a fill quantity determination; thermal imaging by means of an infrared camera to visualize the temperature distribution

Result:

Bulkhead plate between ports leaking; strong fluctuations in the sample of series components



Measurement of evaporators (superheat, spread, latent and sensible power)

Project Objective:

Qualifying various evaporators from different manufacturers. In addition to the performance, the focus was particularly on the temperature spread.

Implementation:

Traversing customer-specific measuring points with the various evaporators; visualization with IPEmotion Plug-in VEP Heat Flow Matrix

Result:

Partly considerable differences between the various manufacturers

Compressor measurement

Determination of the control behavior of an eCV (electric control valve) of a mechanical compressor

Project Objective:

Determination of thermodynamic variables as a function of different eCV flow rates for five different compressors from different manufacturers

Result:

Diagrams according to the client's specifications

Measurement of plate heat exchangers (chillers)

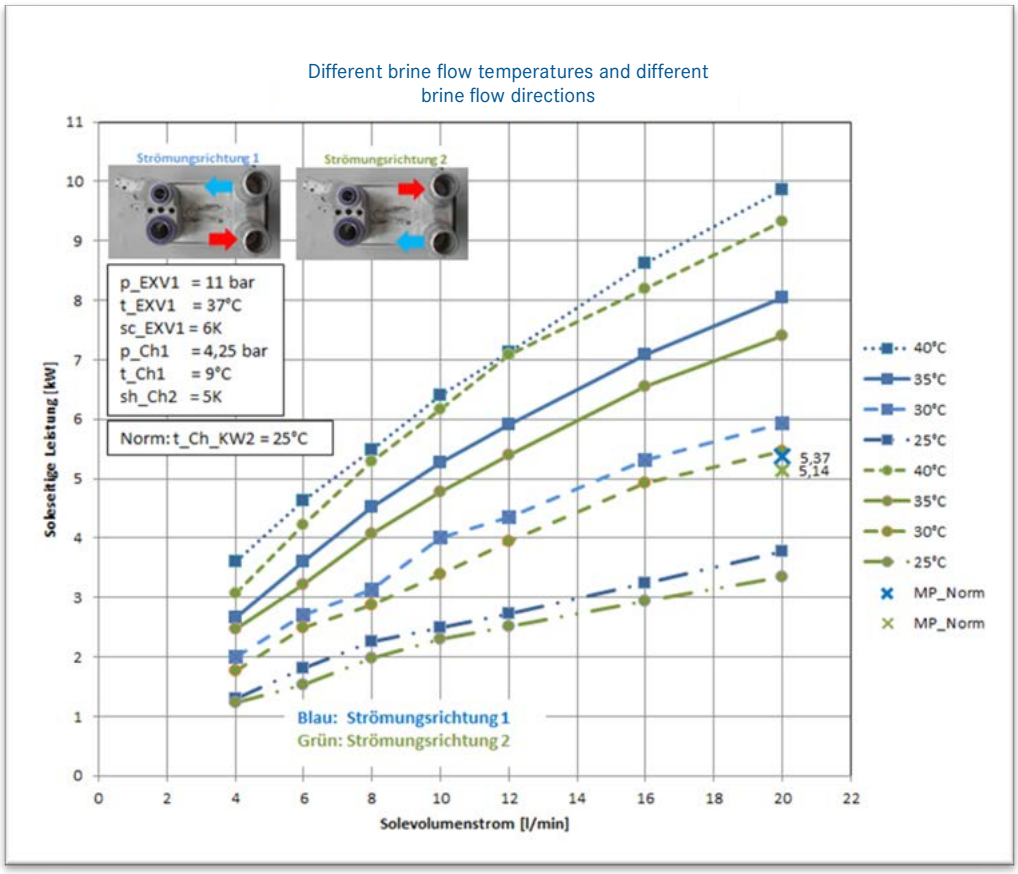
For our customers, we measure and compare plate heat exchangers from different manufacturers or of different types, which serve as brine-cooled condensers or as brine coolers for battery cooling. Here is a direct comparison between the direct current and counter current circuit of a chiller, which was intended for battery cooling. On the water side, the chiller was flowed through by means of an emulator, which simulated the heat input of the battery.

Project Objective:

Qualify a chiller; determine the cooling capacity at different brine flow rates and different temperatures; compare with the capacity with inverted brine flow direction.

Result:

Up to 10 kW cooling capacity; lower capacity when flowing through in co-current instead of counter-current flow



Determine operating strategy

Expulsion of refrigerant from various components

Comparison of different system architectures

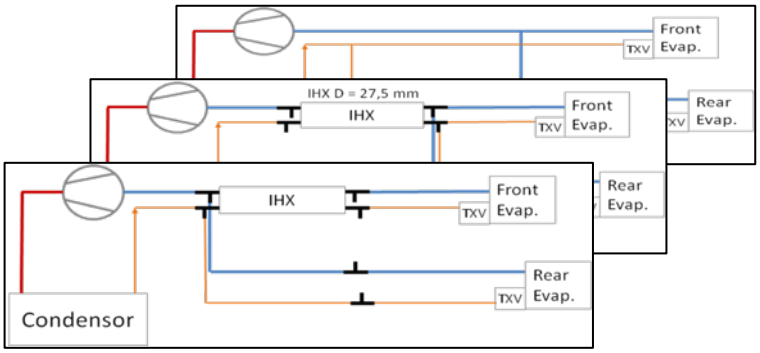
Project Objective:

Test a system with and without IWT (Internal Heat Exchanger) and with different IWT interconnections; identify the most powerful, efficient and operationally reliable variant.

Result:

Small advantages in COP for the variant with the lowest pressure after compressor

Liquid startup



Project Objective:

The compressor is cooled until the housing is full of refrigerant. Then it is started. The relevant parameters are observed in order to detect any exceeding of the operating range.

Noise emissions from refrigerant circuit components in HVAC

Analysis of noise caused by two-phase refrigerant upstream of the expansion valve

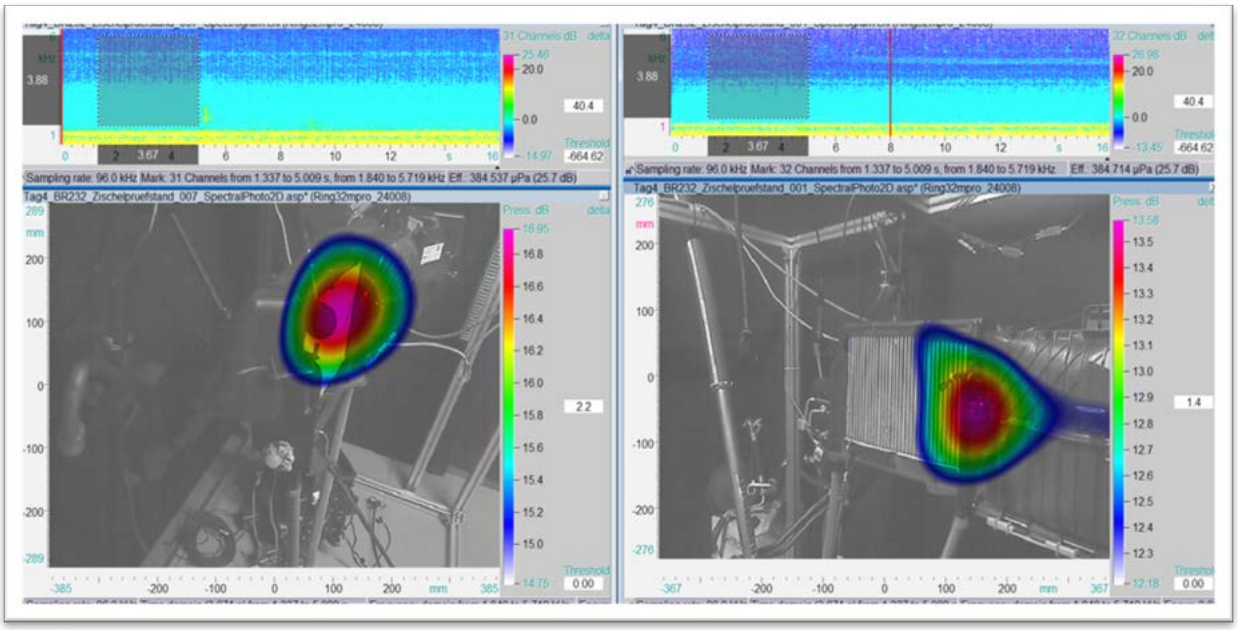
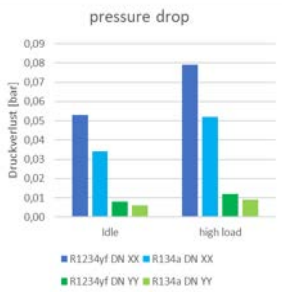


Figure 1: Photoacoustic images noise emission HVAC

Component test bench/refrigerant circuit component tests

The measurement of thermodynamic properties of refrigerant circuit components is of great importance in the development of automotive components (and systems). Our measurement results are often used as a basis for decision-making for series production as well as for the analysis of optimization potentials or unique selling propositions. As a manufacturer-independent test center with many years of cross-industry experience in the field of thermodynamics, IPETRONIK offers component measurements including well-founded evaluations. OEMs and Tier 1 suppliers as well as development partners benefit from our services.



IPETRONIK services with the component test bench

- Precise replication of the specified operating conditions in the refrigerant circuit
- Many years of experience in refrigerant circuit component measurements
- Measurements with R1234yf, R134a and other innovative refrigerant mixtures possible
- Many design options for test cases within a large performance spectrum
- Acquisition and evaluation of important thermodynamic variables (temperature, pressure, OCR, etc.)
- Defined OCR specifications as well as "oil-free" measurements possible
- Automated and time-efficient test operation as well as fully manual control for special operating points
- Performance of long-term tests, COP investigations and calorimetric observations
- Evaluation of the measurement results by expert engineers
- Flexible integration of refrigeration components through own prototype workshop

Test items

- Water-cooled heat exchangers (condensers, gas coolers, chillers)
- Expansion valves (EXV, TXV)
- Refrigerant accumulators and accumulators
- Internal heat exchangers (including differential pressure measurement) and refrigerant lines
- Condensers and evaporators (refrigerant side)

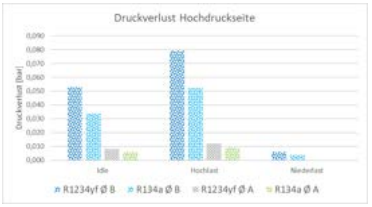
Technical data

Controller	
Pressure range HD/ND	8 to 28 bar/1 to 7 bar
Overheating ND	5 to 25 K (up to 40 K possible)
Hypothermia HD	1* to 25 K (depending on subcooler capacity)
Refrigerant mass flow	50** to 800** kg/h
OCR	0*** ... 5.0 % (higher oil content possible)
Calorimetry	
Condenser capacity	up to 40 kW (limited by refrigerant mass flow)
Evaporator/chiller performance	up to 30 kW (limited by refrigerant mass flow)
IWT performance	depending on size
Thermal state variables	
Pressure safety	1 ... 32**** bar
Pressure ratio	2,5 ... 7.0 bar/bar
Temperature refrigerant	-10 ... 110 °C (in continuous operation)
Temperature brine	0 °C ± 2.5 K
Related sizes**	
KM mass flow/suction pressure	250 kg/h / 2 bar ... 800 kg/h / 6 bar
Evaporator capacity/pressure ratio	30 kW / 3 bar/bar ... 15 kW / 6.5 bar/bar
Test chamber equipment	
Temperature measuring points	up to 8 (refrigerant or brine)
Pressure measuring points	up to 6 (plus 2 differential pressure measuring points)
*	Minimum subcooling can be controlled, but must be stably measurable for caloric determination
**	sizes measured in test cases (depending on further thermal quantities)
***	Oil-free operation possible within the scope of the components under test
****	Limit value for triggering the internal shutdown mechanism

Application examples

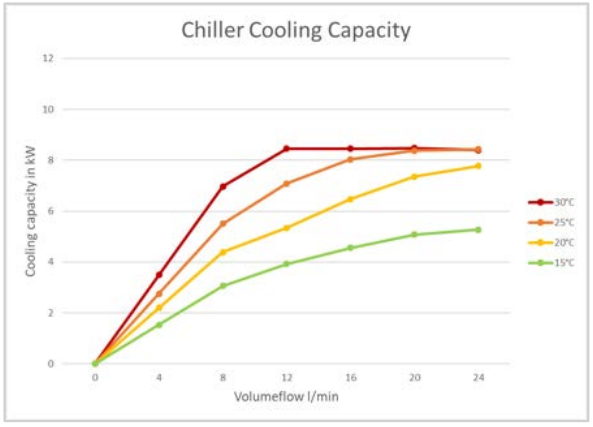
Investigation of an internal heat exchanger (IWT/IHX) e.g. with regard to degree of exchange and pressure drop; measurements with R134a and R1234yf in comparison

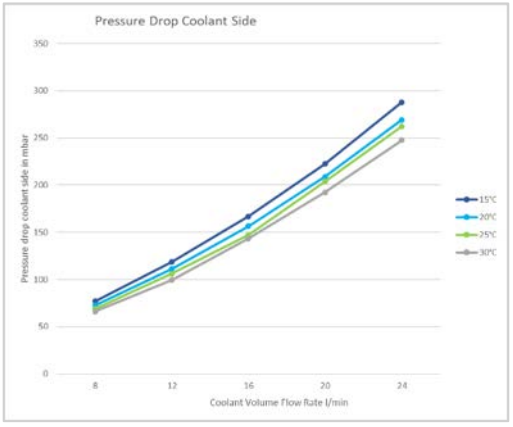
For the thermodynamic consideration of an internal heat exchanger, the so-called degree of exchange is of interest, among other things, in addition to pressure losses and possible heat flows. We record these and other relevant measured values and result variables during measurements for our customers and provide them in the desired format



Investigation of a chiller with R1234yf refrigerant e.g. with regard to cooling capacity and pressure drop

Test specimen: chiller pressurized with R1234yf and water/glycol mixture at specified pressure difference (before expansion valve and after chiller), subcooling before expansion valve, OCR, coolant flow rate and inlet temperature





Development-accompanying investigations of electric refrigerant compressors

Compressor development/testing

In the early development phase of the electric refrigerant compressor, a variety of assurances for durability, efficiency and performance are necessary even before the actual design and process validation tests. For this purpose, there are test cases that require flexibility in their requirements and mapping while maintaining high quality standards. Here, IPEengineering's experience in handling such complex setups is unique in the service field. Through a strong team of engineers and technicians who have built up years of experience in the evolution of refrigerant compressors, the development accompanying tests from the start of development to the finished product provide a complete package in the service sector of the automotive industry.

IPETRONIK services in development-accompanying investigations of electric refrigerant compressors

Thermodynamic studies:

- Characteristic diagram matrix

  Verification of refrigeration performance and efficiency in different pressure/temperature maps up to 800 kg/h mass flow as well as fundamental investigation of pulsation, acceleration and force in stationary map points
- OCR (Oil Circulating Rate)

  Determination of the oil circulation rates in the entire map
- Backpressure tuning

  Tuning of different backpressure systems in the AC/WP characteristic field
- Benchmark

  Comparative studies with competitors
- Liquid startup

  Conditioning of the environment of the test specimen until a desired liquid level is reached in the test specimen, which then has to be pumped out at startup
- Liquid slugging

  Suction of a defined quantity of liquid refrigerant under any load

- Startup with Load

  Startup of the test specimen against a high load in the form of pressure on the high pressure side
- Contamination tests

  Detection of contamination by a particle counter in the system or tests using defined contamination depending on particle hardness and/or particle size
- Thermographic surveys
- Recording of temperature-sensitive components on the power electronics or recording of the test specimen in the long shot with the aid of an infrared camera
- Applications refrigerant compressor

  arbitrary application of measuring points on the entire test specimen

  - Level tube for determining the oil level in the engine housing
  - Attaching temperature measuring points
    - Housing outside
    - Housing inside (e.g. motor windings, scroll inlet, bearings, muffler)
    - Power Electronics
    - Application pressure measuring point for backpressure measurement
- Electrical conductivity

  Component protection stator in water and refrigerant-oil mixtures

  Fuse protection of electric refrigerant compressors in new condition and after graduated aging

  Determination of conductivity and water content of oils

  Measurements of insulation resistance in vehicles
- High-precision phase current measurement using the application of measurement shunts
- Efficiency determination

  Determination of the efficiencies of:

  - Mechanical unit (scroll)
  - Motor
- Durability tests

  Refiner test

  - Assessment of the mechanical assemblies after 500 h of different loads
  - PTCE, HTOE
    - Fuse protection of the power electronics
  - HP test
    - Protection scroll at high load
  - Test endurance run with wet steam portion
    - Protection of components by influencing the lubricant film
- Acoustic studies:

  - Component acoustics

        - Determination of pulsation, acceleration, force and airborne sound
            - Rigid suspension, soft suspension
            - On original carriers (vehicle engine with original holder)
- Vehicle acoustics
    - Hybrid and combustion engine
        - Interior acoustics
        - Transfer Path Analysis
        - Simulation
        - Implementation of optimization measures
    - E-vehicles
        - Noise behavior during fast charging processes (up to 350 kW)
        - Interior acoustics
        - Transfer Path Analysis
        - Simulation
        - Implementation of optimization measures

- Refrigerant

    - Developmental studies can be conducted with R134a, R1234yf, R290, mixtures and R744.

Function test bench refrigerant compressor

In the modern development of vehicle air conditioning and in connection with thermal management, the technical design or the validation of the function of the refrigerant compressor is the focus of the holistic development process. Especially due to the changing requirements in the automotive sector, it is indispensable to reproduce a flawless function of the test item to be tested by means of reliable test bench equipment. Be it in the classic AC mode or in the now increasingly important heat pump mode. The interaction of sustainable hardware in the test bench and the coordinated control in the form of the in-house software IPEmotion make this test bench a unique product in the service sector of the automotive industry.

IPETRONIK services with the compressor test bench

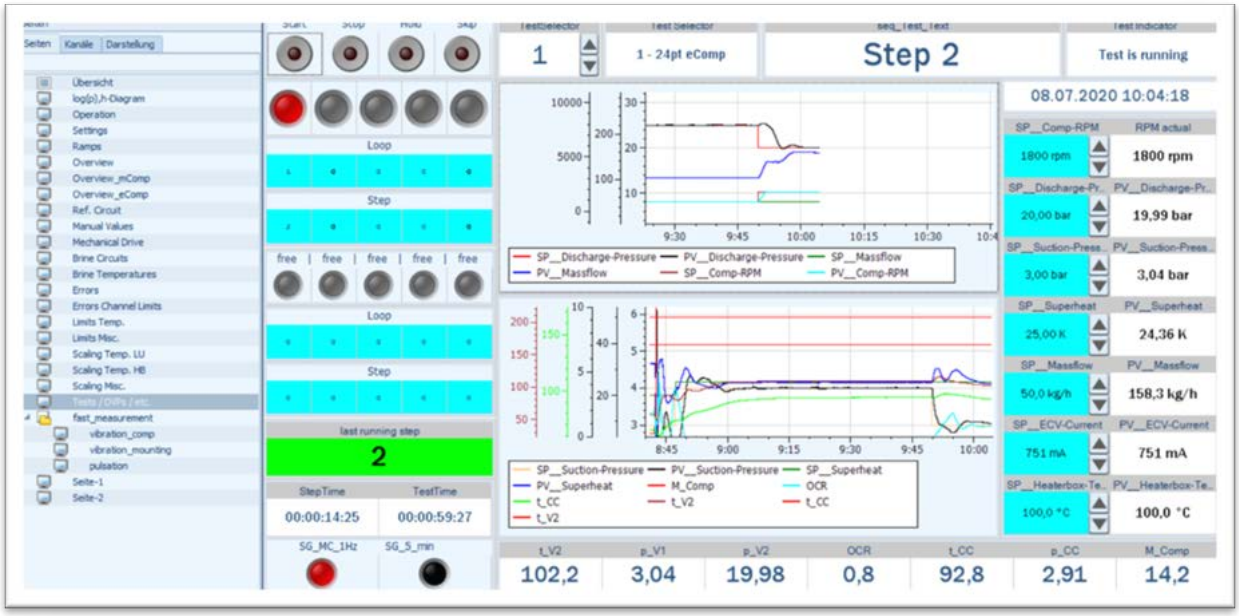
- Measurement and examination of mechanical and electrical compressors regarding:
  - Power
  - Efficiency
  - High Speed Tests for Mechanical Compressors
  - Durability
  - NVH (pulsation, vibration, force)
- Benchmark comparisons
- Standard measuring programs, e.g. 25 pt. matrix eKMV, 22 pt. matrix mKMV
- Programming of customer specific measuring programs
- Mapping of AC and WP load cases
- Versatility with support for common refrigerants R134a, R1234yf, R744, R290
- Individual test specimen setups by adapting the recording of the test specimen
- Arbitrary expansion of sensor and signal capacity for prototypical development
- Investigation of abnormal behaviors of the examinee and support to find solutions.

Technical data

Control and measuring range	
Pressure range high pressure	8 ... 28 bar
Pressure range Suction pressure	1.2 ... 6 bar
Suction gas superheat	5 ... 40 K
Wet steam control	***up to 30 % wet steam***
Refrigerant mass flow	30 ... 800 kg/h
Ambient temperature of the test specimen	-30 ... 120 °C (-22 ... 248 °F)
Air velocity test chamber	0 ... 8 m/s (VDA 6 m/s standard)
Measuring range torque	0 ... 50 Nm
Mechanical compressor	
Control magnetic coupling	on/off, 12 VDC & 24 VDC
Control ECV	0...1000 mA
Compressor speed	0...10000 rpm
Electric compressor	
Control	e.g. LIN/CAN IPEmotion
Supply voltage	0 ... 1000 V / 0 ... 40 A 0 ... 80 V / 0 ... 340 A

Application examples

Excerpt of an automated test



Endurance test bench IPEload

Component development in "mini format"! The little brother to the IPEcomp is the IPEload auto. As already mentioned with the IPEcomp, this product can be used to determine the properties of the test specimen. Here the focus is more on durability and lifecycle performance. This is realized by means of Raffertests specified in the customer's specifications, or the determination of the test matrix is worked out individually with the expertise of IPEengineering. Due to the small installation space and the resulting low space requirement, this load box can be used for other development-relevant topics around the refrigerant compressor. In conjunction with a separate climatic test cabinet, the test specimen can be subjected to various temperatures, both in the positive and negative Celsius range.

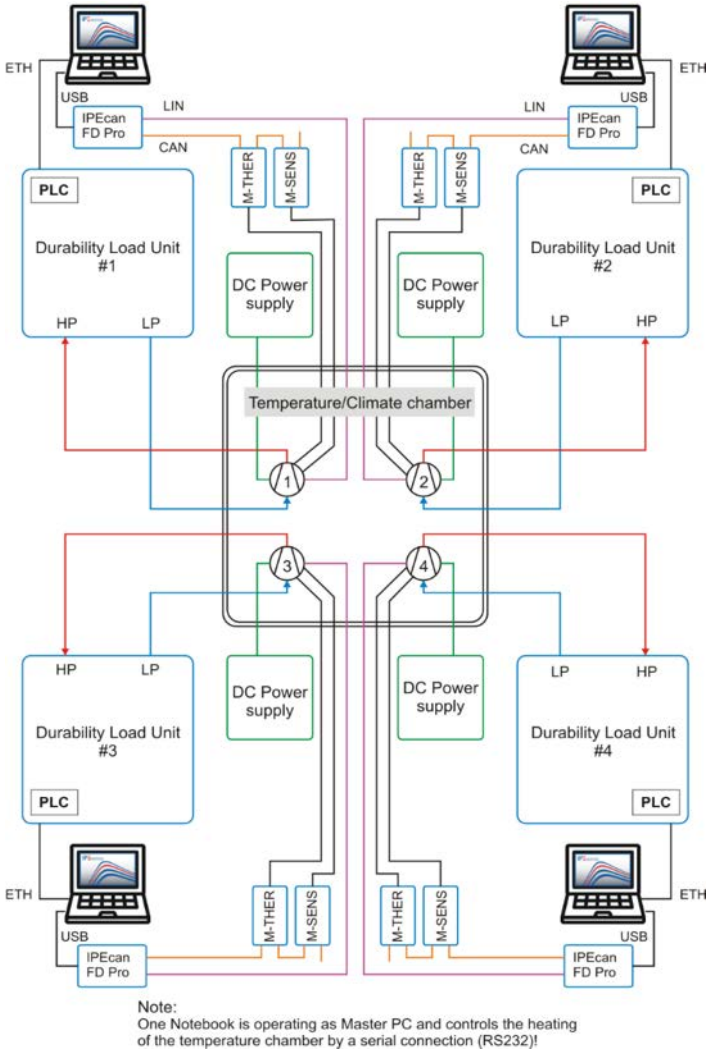
IPETRONIK services with the endurance test bench

- Measurement and study of electric compressors with respect to:
  - HTOE Testing
  - PTCE Testing
  - Durability test
  - Raffertest (Lifecycle Performance)
  - Thermography for heat development on the test specimen or on the circuit board
- Suitable for R134a, R1234yf, R744, R290 and refrigerant mixtures
- Custom prototype builds
- Arbitrary expansion of sensor and signal capacity for prototypical development
- Examination of behaviors over a whole gerafferten life cycle of the test specimen.

Technical data

Control and measuring range	
Pressure range high pressure	8 ... 28 bar
Pressure range Suction pressure	1.2 ... 6 bar
Suction gas superheat	5 ... 40 K
Refrigerant mass flow	30 ... 400 kg/h
Electric compressor	
Control	e.g. LIN / CAN IPEmotion
Supply voltage	0 ... 1000 V / 0 ... 40 A 0 ... 80 V / 0 ... 340 A

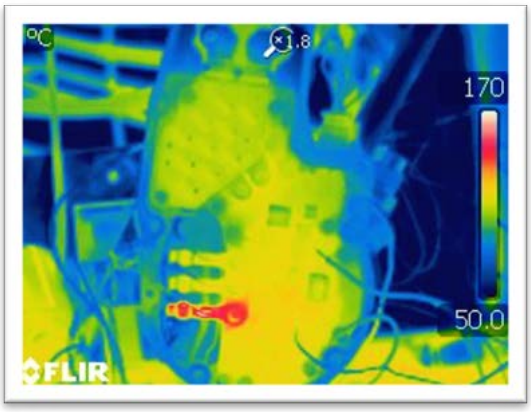
Design of the endurance test bench

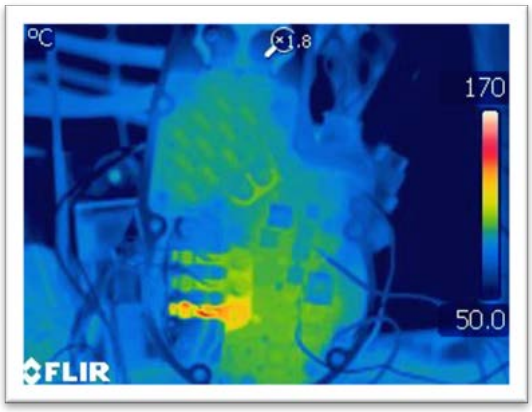


Note:
One Notebook is operating as Master PC and controls the heating of the temperature chamber by a serial connection (RS232)!

Application examples

Thermographic examination on the endurance test bench using an IPELoad auto





Contamination

Particle counter

A new type of lifecycle assurance at the component and system level involves the representation and recording of the behavior of foreign bodies within the plant. Due to automated manufacturing and various production processes, sources of defects are increasingly emerging that can have a lasting impact on the quality of the end product. This is exactly where IPEengineering comes in and offers a further component within the scope of its services, with which many properties of an end product can be positively influenced. In cooperation with an independent test laboratory, defined contamination capsules are produced, whose contamination is then introduced into the system to be tested. After completion of the test series, the components of the system are brought to the test laboratory for analysis of the particles contained therein and evaluated.

IPETRONIK services in the field of contamination

- Online particle counting in AC and WP systems or special setups in coordination
- Use in refrigerants: R134a, R1234yf, R744 and refrigerant mixtures
- Analysis of components (in cooperation with a partner laboratory)
- Advice on selection of contamination samples and test specifications
- Endurance test
- Reproduction of quality anomalies
- New part inspections
- Components tests

Technical data

Measuring range	
Ambient temperature	5-40°C
Flow rate in ml/min	2000
Measuring range in µm	15-2000
Max. Concentration particles / µm	500

ACOUSTICS

Climate acoustic chamber

Acoustics development refrigeration circuit passenger car, cool-down measurements for refrigeration performance, representation of extreme climatic conditions as vehicle environment

The climate-acoustic chamber with its flexible conditioning from cold to heat climate offers ideal boundary conditions to realistically load the heating/air conditioning system of a vehicle. With the control of the temperature from -20°C to +50°, the humidity, the sun simulation by means of infrared lamps as well as the vehicle inflow with up to 32 km/h driving wind, a variety of climate zones can be simulated as vehicle environment. In addition to the thermodynamic usability, the design as an acoustic semi-free-field room together with the hydrophobic attenuation of all conditioning components allows the authentic evaluation and measurement of acoustic phenomena. Typical applications include the testing and subjective evaluation of in-vehicle air conditioning compressors, HVAC noise (evaporator hiss) and general transfer path analysis of the refrigeration circuit.

IPETRONIK services in climate acoustic chamber

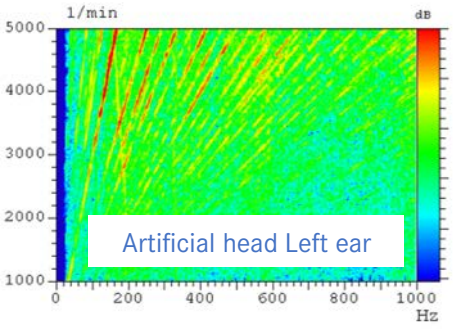
- Cool-down test (simplified climatic wind tunnel conditions)
- Filling quantity regulations for vehicle refrigeration circuit
- Measurement of cabin and exterior noise, vibration at transfer paths, pulsation in refrigerant lines and vehicle operating data (CAN bus) under cold, comfort and heat climates
- Testing of parking heaters with regard to heat output and acoustics

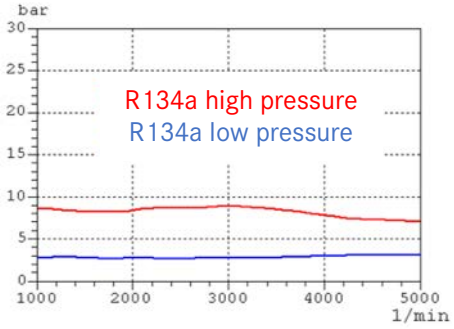
Technical data

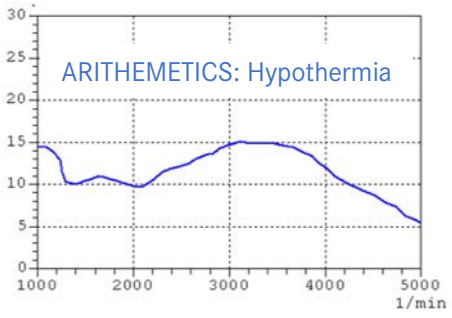
Semi open field room for vehicle testing	
Length	6,5m
Wide	3,5m
Height	2,96m
Air temperatures	-20°C to +50°C
Maximum waste heat of the test specimen	25 kW at -20°C
Relative humidity	20% to 70%, adjustable from +10°C
Sun simulation	Max. 1200 Watt/m2 (infrared)
Recirculation speed	Max. 32 km/h
Exhaust gas extraction	Yes, silenced
Acoustic measurement technology	
PAH system (MüllerBBM)	120 channels for measuring acoustic and vibration, pressure pulsation and CAN bus. In addition, the established measurement technology from IPETRONIK
Acoustic camera (GFAI)	Measurement system for localizing acoustic emissions

Application examples

Typical acoustic measurement of refrigeration circuit noise in the vehicle cabin incl. online analysis







Operation of PAK computer via iPad

Measurement / optimization of external noise of scroll compressors

However, the advantage of electrically driven compressors in terms of climate comfort (pre-cooling of the vehicle without the drive train running, similar to auxiliary heating) also embodies the acoustic worst case. Without masking noise from tires or drive train, the compressors often cause noticeable operating noise, which is perceived as particularly disturbing in the vehicle's exterior noise. As a standard, the vehicle is preconditioned at +40°C and 40% relative humidity and the air conditioning system is measured in cooling mode with regard to airborne noise, vibration, etc. The air conditioning system is also measured in cooling mode. In addition to evaluating the components involved, encapsulation of the compressor or damping measures of the body are tested as typical secondary measures to improve exterior noise.

Measurement / optimization cabin noise of compressors

The highly sensitive acoustic situation in the cabin of a stationary but electrically air-conditioned vehicle is influenced by the excitation primarily from the air-conditioning compressor, its transfer paths (vibration, airborne sound, pulsation) and the wide-ranging noises from the front fan and the cabin blower. The typical customer setting of minimum blower speeds with simultaneously low target temperatures for the cabin often allows humming noises, modulating and rough-sounding components or even higher harmonic orders of the air-conditioning compressor to penetrate. Because of the hardly effective masking by other noises, very low levels are often sufficient here to leave a disturbing sound impression. By means of airborne sound recording via dummy heads (front and rear seats), a database is available for authentic evaluation in the AUDIO studio. Also the influences of minimal changes of various operating parameters can be adjusted, measured and analyzed in their effect. The typical optimization steps with regard to compressor cabin noise include, in addition to supplier-side measures, various improvements to vehicle transfer paths, as well as application-related scopes and the separate measurement of fan noise as the data basis for an optimized application.

Loadbox structure isolates transfer paths of the refrigeration circuit

The transmission of noise from the air-conditioning compressor into the vehicle cabin usually takes place via various transfer paths. These mainly consist of vibration excitation by the compressor bracket, airborne noise radiation from the compressor and vibration transfer via refrigerant and electrical lines connecting the refrigeration circuit to the vehicle. The loadbox design deactivates the vehicle refrigeration circuit, leaving only the compressor itself in operation and its immediate transfer paths (vibration mount and airborne sound). Due to the test bench compatible loading of the compressor by the loadbox, complete load profiles can be run without the transfer via refrigerant lines & HVAC. In addition, the noise of the front fan and the cabin blower is eliminated. The vehicle body with load box has proven itself in many ways in the optimization of transfer paths and the improvement of cabin noise.

Acoustic camera visualizes dominant emission points of disturbing noises

The acoustic camera, which can be easily used in the acoustic chamber with its low-semi-reflection lining, helps with rapid local containment and identification, especially in the case of previously unknown noise phenomena. It can be used for overall levels and narrowband filtered noise components. The synchronous acquisition of acoustic measurement data together with vehicle operating data, which are combined in a measurement system via Can-Bus, proves to be particularly advantageous here.

Subjective evaluation of acoustics by test persons

The measurement setups and processes for measurement and analysis purposes are also often used for subjective evaluation of the acoustic behavior of the test specimens. Here, the measurement and control technology is used for monitoring and real-time display of various operating variables. In many cases, a mix of experts and non-technical vehicle users is used to statistically validate a typical customer evaluation of the noise behavior.

Acoustic chamber with HV charging column

Acoustic development of e-vehicles, testing of HV charging processes, acoustic measurement of general technical superstructures

The acoustic chamber with HV charging column offers a wide range of possibilities for acoustic testing of vehicles, vehicle subsystems and general technical superstructures. Designed as a semi-open-air room with large hinged doors on two sides, the acoustic chamber has a vehicle lifting platform that allows very flexible control and modification of test setups already being tested. The combination of HV charging station and acoustic environment supports tests and development steps, as recently demanded in automotive engineering with purely electric vehicles and fast charging technology.

IPETRONIK services in the acoustic chamber with HV charging column

- Vehicle acoustic evaluation during HV charging up to 350 kW (with cooling demand on vehicle-internal AC system)
- Measurement of HV charging power and specific parameters during the charging process (charging current, voltage, temperature, etc.)
- Standard test for isolation of transfer paths with load box (eKMV active, remaining vehicle refrigeration circuit deactivated).
- Construction and measurement of larger acoustic components and vehicle subsystems
- Use of the clean chamber for general acoustics tests on technical superstructures

Technical data

Semi open field room for vehicle testing	
Length	6,5m
Wide	4,7m
Height	4,1m
Max. Vehicle width	2,5m
Max. Vehicle height	3m
Max. Vehicle length	6m
Air temperatures	10°C to 40°C
Integrated lifting platform	3,5t
Exhaust gas extraction	-
Superchager fast charging station	
Charging power	350kW
Max. Voltage level (DC)	950V
Max. Current (DC)	500A
Contact	CCS-2 with DC charging function
Acoustic measurement technology	
PAH system (MüllerBBM)	120 channels for measuring acoustic and vibration, pressure pulsation and CAN bus. In addition, the established measurement technology from IPETRONIK
Acoustic camera	Measurement system for localizing acoustic emissions

Example of a charging cycle of an eVehicle

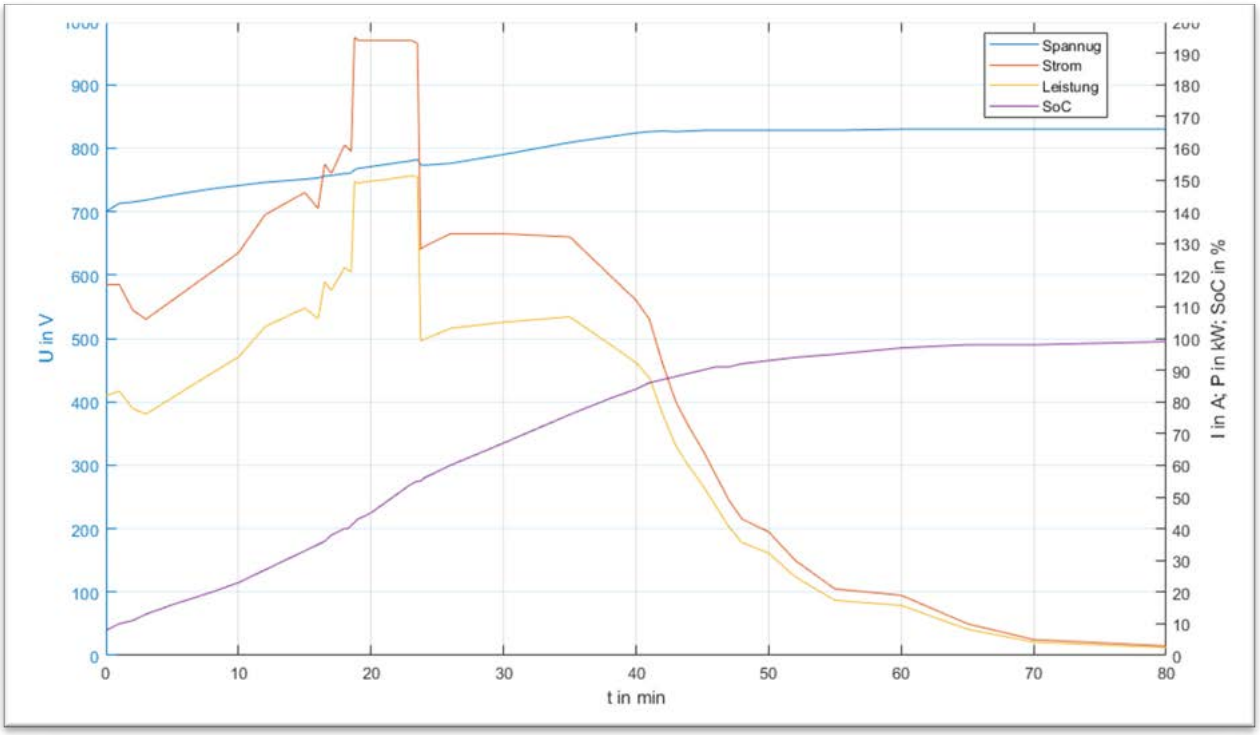


Figure 2: Charging curve e-vehicle: voltage level (blue), retrieved charging power (yellow), charging current (orange) and vehicle state of charge SoC (purple).

Application examples

Test series HV charging power vs. efficiency

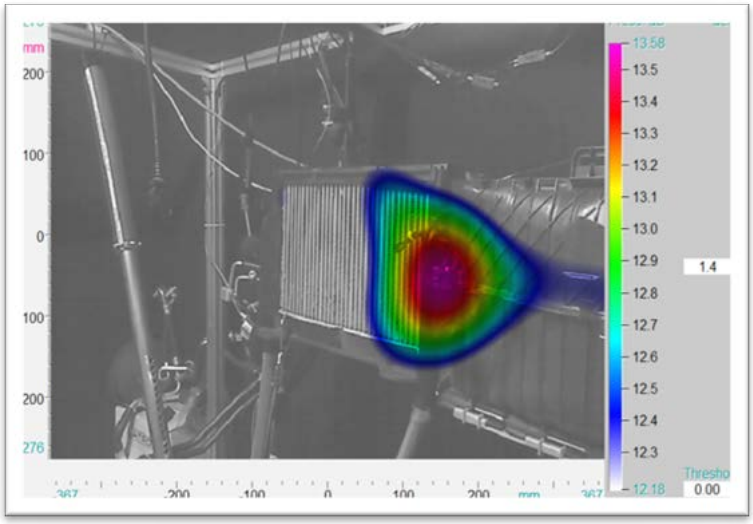
A vehicle can start a charging process with different residual states of charge of the powertrain battery and different starting temperatures. A wide range of parameters of the electrical and thermal energy flow can be recorded and analyzed. Another degree of freedom is the specified charging power/speed, which can be varied and which affects the energy balance.

HV charging power vs. noise test series

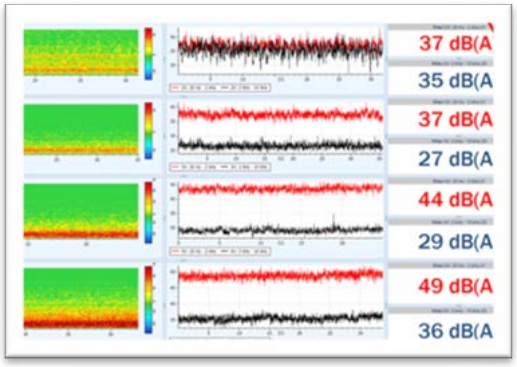
At low charging powers of up to approx. 150 kW, there is usually very little waste heat, so that the vehicle's air conditioning system is not required. However, at higher charging powers, which are intended to keep a stopover on long-distance trips as short as possible, high speeds of the air-conditioning compressor and the front fan are to be expected, which can cause acoustic noise. The coordination of HV charging power vs. noise development can affect comfort-relevant and legislative criteria here (TA noise).

NVH system acoustics test bench

With its NVH system test bench, IPETRONIK offers the possibility of recording and analyzing the noise development at the HVAC (air conditioning unit) using in-house acoustic measurement technology. For this purpose, microphones are placed in the near field of local sound sources and, if necessary, the so-called acoustic camera (GFAI, see figure on the right) is used for sound localization. Sensors for vibration and pulsation of the refrigerant can also be placed in the system.



In order to obtain as little extraneous noise as possible and to acoustically measure only those components that are located inside the vehicle, the components of the refrigeration circuit are decoupled from each other. This means that the HVAC sits in a separate acoustic chamber, which is acoustically insulated and sound-absorbing lined on the inside, as well as enabling different load conditions on the e.g. evaporator via temperature and humidity control. The test bench can thus be operated according to customer specifications and offers various possibilities for different operating conditions.



The evaluation of the signals is done via the in-house software IPEmotion and can be displayed in different representations, such as Campbell diagrams, levels etc..

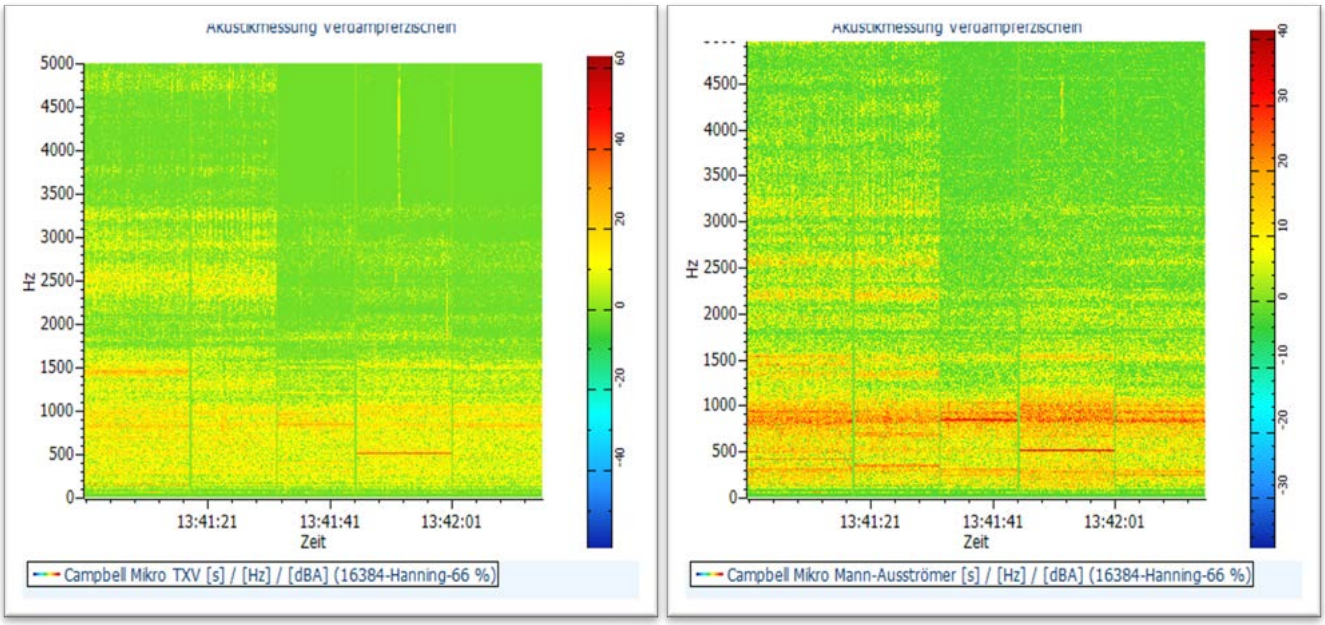
Ipetronik stands for flexibility, because due to the experience in the field of air conditioning, we are also able to make any kind of modifications to the refrigeration circuits. It is possible to modify the refrigeration circuit in places where unwanted noises occur. In the example you can see an evaporator, which has been equipped with sight glasses in order to get an insight into the places where noises occur. We have highly trained personnel and workshops for this purpose.

IPETRONIK services with the acoustic system test bench

- Acoustic measurements on the HVAC (air conditioning box), which sits in the car under the dashboard, to simulate the noise generated by the air conditioning system inside the car
- Special bodies
- Acoustic measurements on: Evaporator, EXV, piping, etc.
- Construction of the HVAC with different acoustic insulation materials.
- Geodesic layout of the air conditioning system according to CAD data

Technical data

Acoustic test bench	
Temperature range at the evaporator	10 ... 50 °C
Relative humidity	20 ... 60 %
Measuring equipment	
Microphone	Sensitivity 50 mV/Pa
Accelerometer	10mV...100mV/g
Temperature / Pressure / Software	Ipetronik measurement technology
Acoustic camera	



Example of two Campbell diagrams. Representation of the microphones at the TXV and at the Mann outflow.

Application examples

Acoustic measurements on the HVAC (air conditioning) box, which sits under the dashboard, to simulate the sound of the air conditioning system inside the vehicle as the driver would perceive it.

Construction of the refrigeration circuit according to customer specifications with measuring points (pressure/temperature) upstream and downstream of each component, both on the refrigerant side and on the air side. Arrangement of microphones and acceleration sensors in the acoustic chamber. Control of actuators such as fans and EXV's (Electronic Expansion Valve) possible.

Special bodies.

For example, changed line routing, installation of an EXV (electronic expansion valve) instead of TXV (thermostatic expansion valve), different evaporator setups.

Acoustic measurements on:

Single evaporator plants, double evaporator plants, EXV / TXV and chillers etc. possible.

Construction of the HVAC with different acoustic insulation materials.

Foams, no drip tape, weights, enclosures, decoupling etc.

Geodetic construction of the air conditioning system on site according to CAD data

This means that the refrigeration circuit is built on a rack according to customer specifications and CAD drawings. The structure thus corresponds to the position of the components as they are arranged in the vehicle.

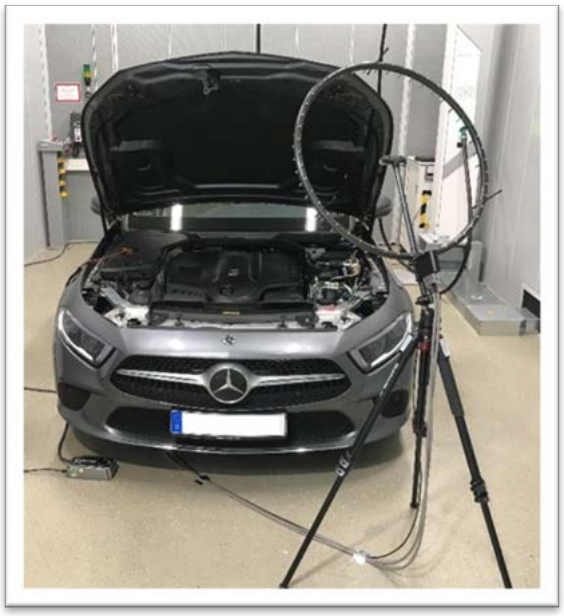
Test rig design:

Condenser Box & Acoustic Chamber; Line Structure & Feedthrough; Sight Glass & Metrology.

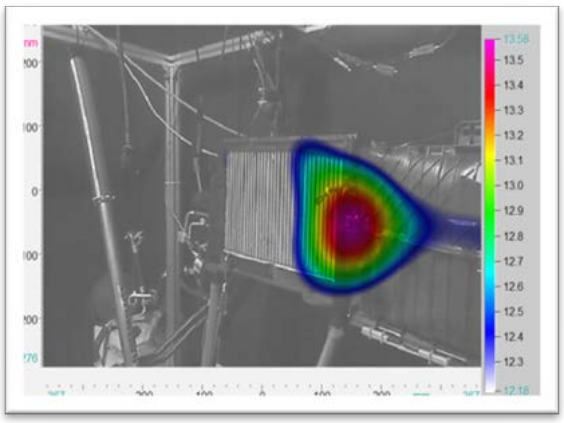
Acoustic camera

Sound localization with acoustic camera on passenger cars, on subsystem and aggregate test benches, on non-automotive projects

As is well known, multi-channel microphone measurements allow the evaluation of sound propagation at different positions. This allows conclusions to be drawn about different assemblies and their acoustic radiation behavior.
However, the spatial resolution when using common microphones is limited and the exact assignment of where a sound is actually emitted is often very inaccurate.
Here, the use of the acoustic camera offers a practical and fast possibility of identifying dominant partial sound sources. By means of a ring-shaped arrangement of 48 individual microphones (microphone array) and a video camera in the center of the ring, the sound radiation is initially recorded synchronously with the video image data. The analysis of the different propagation times of the sound radiation of individual partial sources allows the directional assignment of their radiation locations. This acoustic mapping of the sound field can be superimposed on the grayed-out video image as a colored decibel distribution, so that in many cases a dominant partial sound source can be identified at first glance.



Microphone array with central video camera in front of vehicle



Localization of a hissing noise at the component test bench: Dominant radiation at the frame of the evaporator on the right side

IPETRONIK services with Acoustic Camera (GFAI)

- Fast results for sound localization - Automotive and Non-Automotive
- Synchronization with IPETRONIK measurement technology via CAN bus
- Wide range of applications for the initial evaluation of new acoustic phenomena
- Targeted steps for local, temporal and frequency-related containment of sound radiation
- Extended database for detailed AUDIO evaluations in the recording studio

Application examples

Acoustic camera visualizes dominant emission points of disturbing noises

The acoustic camera with its low-reflection lining, which is easy to use in the acoustic chamber, is particularly helpful for previously unknown noise phenomena with its rapid local containment and identification. This can be applied for total levels and narrowband filtered noise components.

Acoustic Camera Photo Mode and Video Mode

For the stationary operation of a DUT, a static analysis image of the spatially distributed sound radiation superimposed on the grayed-out optical camera image is a suitable form of analysis for sound localization. Analysis results of this type can be examined and stored like a photo.

In the case of unsteady operation of a test object, such as the speed ramp-up of a power unit, the video mode of the acoustic camera is ideal for sound localization. The principle of superimposition is the same as for static photos, but in the form of two time-synchronized video films. This means that moving objects (moving parts of a machine) or changing geometries (opening valves or flaps) can be viewed as an optical video and their location-dependent sound emission can be analyzed at the same time.

Synchronous additional variables via CAN bus

The synchronous acquisition of acoustic measurement data together with vehicle operating data, which are combined in a measurement system via Can bus, proves to be particularly advantageous here. In transient operation, for example, switching operations of valves, changed system pressures or other changes in operating variables can be directly assigned to a conspicuous change in sound radiation.

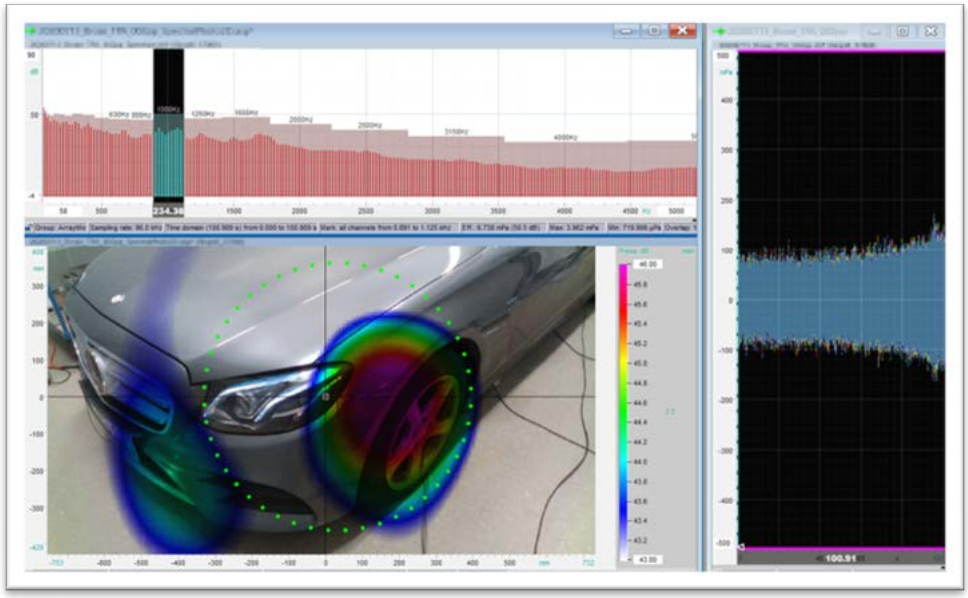
Identification of "acoustic leakage

Various units in automobiles or other technical applications are enclosed in acoustically insulating capsules to reduce sound radiation. When developing or testing the quality of such encapsulations, the acoustic camera can be used in a very targeted and efficient manner. Small, acoustically effective openings or weak points in the capsule design can be quickly identified as "acoustic leakage".

Analysis variant 1

From the raw time data (right) a spectral part (above, marked selection) is filtered out, whose sound localization is analyzed via the array (position: green dots in the photo below left).

The result of the sound localization shows for the selected frequency range a dominant radiation in the area of the front left fender

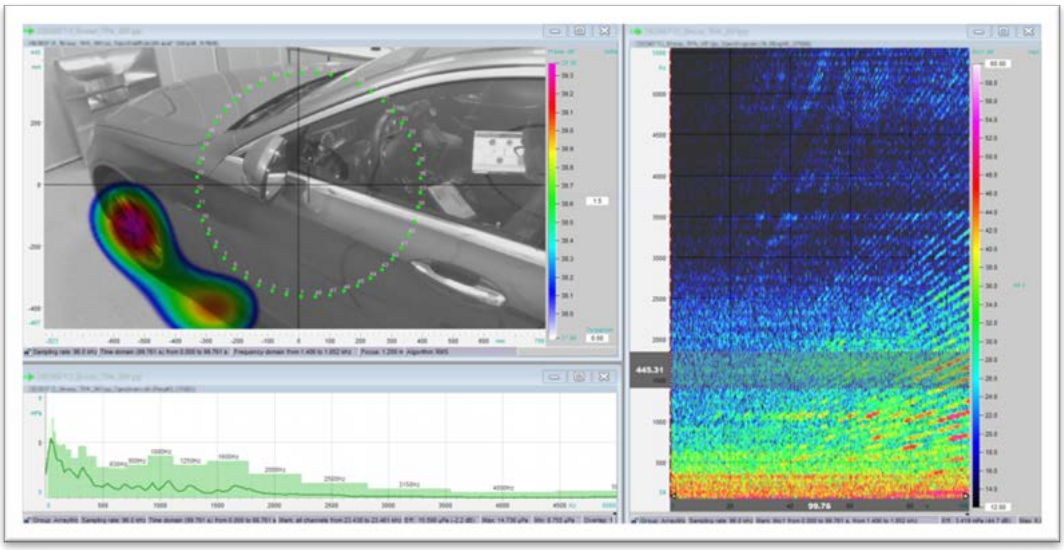


Analysis variant 2

In the Campbell diagram showing a speed ramp of the air-conditioning compressor, a spectral component is marked (right).

The sound radiation is recorded and analyzed via the array: The dominant sound radiation is via the front wheel arch.

The video mode of the acoustic camera is particularly advantageous here, as it auralizes and (!) visualizes the spectral conspicuity over time in the final speed range of the air-conditioning compressor.



Quiet Air Test Bench

Testing air flow systems and components

With the Quiet Air Test Bench, IPETRONIK offers the possibility of testing air-flow systems and components. The Quiet Air Test Bench has established itself as a multifunctional tool for testing vehicle ventilation.
The focus here is on aeroacoustic and flow-physical issues. The compactness and mobility of the test bench allow the realization of various test architectures from standardized to specific setups. The in-house developed test rig is used solo, but also in combination with other test equipment. Acoustic chambers and climatic-acoustic chambers are available for aeroacoustic tests.

Quelle: https://media.daimler.com, Ablagenummer: 10C1104_16

IPETRONIK services with the Quiet Air Test Bench

- Precise sensor technology for recording air condition variables
- Calibrated air mass flow over two Venturi measuring sections
- Calculation algorithm according to DIN EN ISO 5167-3
- High-performance blower and high-efficiency silencers
- Variable iris orifice for adjustable suction resistance
- Flexible hose, flange, ring pressure line assortment
- Inline calming chamber for high flow homogeneity
- Export of all common measurement data formats
- Active or passive versatile air supply
- Compatibility with a wide range of test items and measurement tasks
- Total vehicles
- Exhaust air, leakage air, air distribution
- Air conditioners
- Aeroacoustics and performance
- Air ducts
- Aeroacoustics and pressure drop
- Outlet
- Aeroacoustics

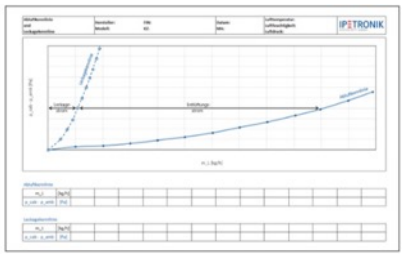
Technical data

Quiet air test bench	
Air measuring section I	0.5 to 4.5kg/min (accuracy: +/-0.25%rel)
Air measuring section II	1.3 to 11.5kg/min (accuracy: +/-0.10%rel)
Differential pressure sensor	Endress+Hauser, Deltabar PMD75, 0 to 1000Pa (accuracy: 0.1%rel)
Absolute pressure sensor	STS, ATM.ECO, 800 to 1200mbar (accuracy: +/-0,01%rel)
Temperature-humidity sensor	Rotronic HC2A, 5 to 60°C (accuracy: +/-0.1°C) Rotronic HC2A, 10 to 75%r.H. (accuracy: +/-1%r.H.)
Blower maximum power	10kg/min @ +350Pa dynamic pressure
Iris aperture Maximum aperture	10kg/min @ -300Pa Intake resistance

Application examples

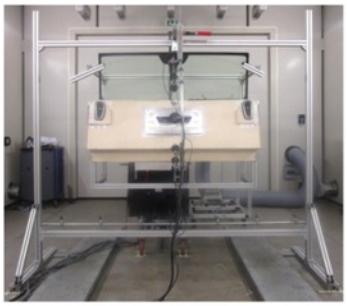
Exhaust air and leakage air characteristics of complete vehicles

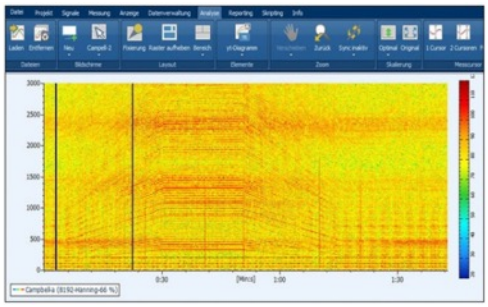




Exhaust air, leakage air and venting curves calculated from these are vehicle-specific and are measured with inactive vehicle blowers and closed fresh air dampers. For performance and aeroacoustic measurements of ventilation systems, these curves allow correlation of load-heft-typical air mass flows based on the overpressures in the passenger compartment, whose sensor technology does not influence the system behavior.

Air supply of box setups for aeoracoustic measurements of ventilation systems





Aerocustics are measured in sound-absorbing acoustic chambers. For ventilation systems, box setups have become established that reproduce the interiors close to the bulkhead in wood and with real front windows in conformity with CAD. The quiet air test stand is located outside the chamber and is connected to the air-conditioning unit via an aperture. The intake resistance is adjusted by means of its iris orifice and the air mass flow is measured by means of its venturi measuring sections. The focus is on design potentials for acoustic optimization of ducts and diffusers.

Pre-development decoupling and holder systems

Solutions for acoustic and vibration engineering tasks

Vibroacoustics are playing an increasingly important role in the series development of passenger cars. In order to minimize unwanted vibrations and background noise, precisely designed decoupling systems for auxiliary units are required.

IPETRONIK offers its customers innovative concepts for the pre-development of decouplers and retainer systems for this purpose.

Within the scope of flexible test bench setups, vehicle measurements close to the customer or even combinations of both areas, meaningful NVH measurements with high-precision measurement data acquisition can be realized.

In addition to vibroacoustic measured variables (force, vibration, airborne sound, pulsation in refrigerant lines, etc.), this also includes relevant operating variables (temperatures, pressures, speeds, etc.) and, if necessary, other variables from the digital data streams from the vehicle board network.

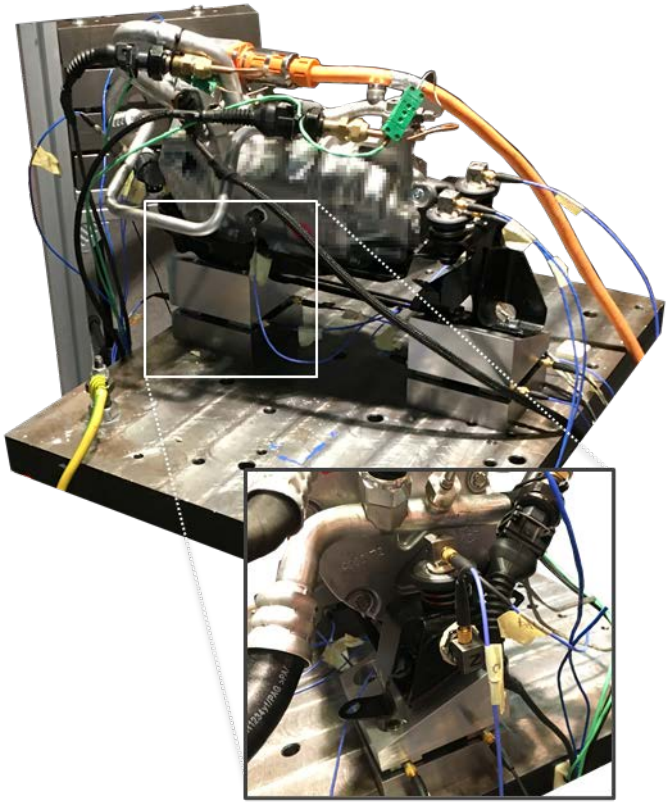


Figure 3: Test rig setup of a decoupling system

IPETRONIK services in the pre-development of decouplers and retainer systems

- Conceptual design of decoupling systems taking into account target parameters and customer requirements (vibroacoustic, structural-dynamic, conceptual, package)
- Construction and investigation of prototypical decoupling systems on test benches
- Construction and investigation of prototype decoupling systems in the vehicle system (e.g. in the body of a predecessor model)
- Concept verification and functional proof through measurement operation and/or simulation
- Decoupling and holder system optimizations - basic investigations and target-oriented system adaptation
- Benchmark studies

Application examples

Concept verification in the vehicle system

By setting up customer-specific decoupling systems equipped with extensive measurement technology inside a vehicle body, the advantages from the field of test bench measurements can be combined with those of vehicle measurements. The decoupled auxiliary units can be operated both on the vehicle and by applying external loads, which means that the system properties of new types of decoupling systems can be experienced in the passenger compartment, for example, as early as the development phase.

New development of a multistage decoupling of an electric air conditioning compressor

By combining conceptual design, simulation, tests on test benches at defined compressor load and operating conditions (using the IPELoad load unit), and final validation in the vehicle, IPETRONIK offers its customers comprehensive expertise in the field of system development.

Depending on the effect of necessary modifications to the prototype status (for example, due to updated package specifications), these can be evaluated using measurement data, analysis and/or suitable simulation. This ensures extensive technical monitoring throughout the entire development process.

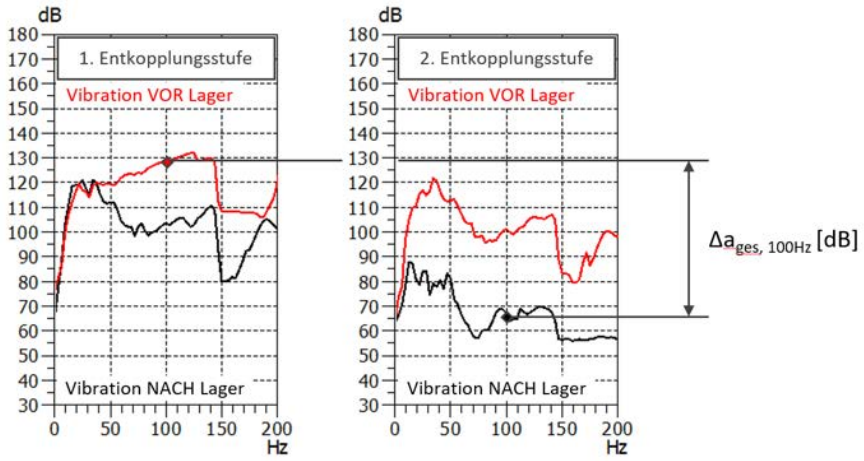
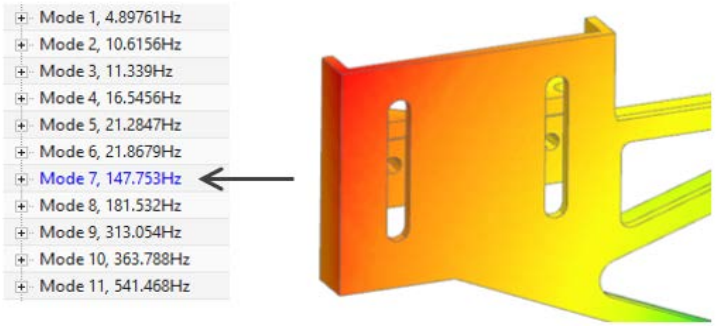


Figure 4: Acceleration before and after individual system decoupling stages during testing of a holder system on a body replacement test rig

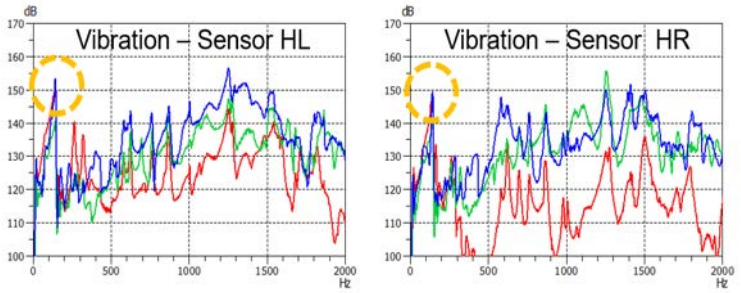
Acoustics simulation

Simulation (CAE) of structural dynamics and sound radiation

The acoustic development of automotive components benefits significantly from the interaction of testing and simulation.
While general experience and analyses of measurements form the basis for new developments, simulation allows the evaluation of components and concepts in advance, independently of time-consuming and cost-intensive hardware. Thus, it is possible to select from several designs, weak points can be identified and avoided at an early stage.
Thus, the parallel management of simulation and testing allows a constant mutual optimization - the quality of each hardware construction stage benefits from the previous simulation; likewise, the accuracy of the simulation models can be optimized by comparison with the subsequently available measurement data.



Analysis 1: Simulation of structural dynamics - Mode 7 is identified as component resonance at 147.8 Hz.



Analysis 2: Measurement data from vibration sensors - at the speed ramp of the unit, a strong overshoot is detected at the support frame at approx. 150 Hz => here the 1st order (= speed) of the unit runs through a component resonance

IPETRONIK services in acoustic simulation

- Modal analysis
- Simulation of airborne sound radiation as sound pressure or sound power based on structural dynamics
- Forced oscillation via unit excitation or via measurement data
- Mutual optimization of simulation models and hardware construction stages at each iteration step
- Detailed simulation models due to high number of channels in experiments in refrigeration circuit acoustics
- Experience values in the simulation of the decoupling of air conditioning compressors

Application examples

Structural Dynamics

Using component geometries and material data, natural resonances and the vibration shapes can be simulated. The unit excitation can be used as excitation data for this purpose.

Decoupling

In particular, the development of decoupling systems benefits from the simulation of structural dynamics. Here, the simulation model links the respective excitation with the structural dynamics of the assemblies, which ideally act as rigid bodies or as compliant springs/dampers. By simulating the structural dynamics, the basic design of the components can be dimensioned and, for example, spring stiffnesses can be determined that produce the desired decoupling.

In typical real cases, component weaknesses of insufficiently rigid components can be identified by simulation and optimized constructively before the hardware is manufactured. This is a special added value of the simulation, since components with stiffness dips in decoupling-relevant frequency ranges do not represent a sufficient impedance jump to the respective compliant bearing and thus reduce its decoupling effect.

Special importance is attached to the simulation of linked decouplings which influence each other. A typical case is the disturbing structure-borne sound connection via pipes or cables. In the case of a refrigeration circuit with a decoupled air conditioning compressor, the refrigerant lines may have higher stiffnesses than the actual compressor decoupling and thus require the simulation to consider two spring/damper arrangements connected in parallel.

Sound radiation

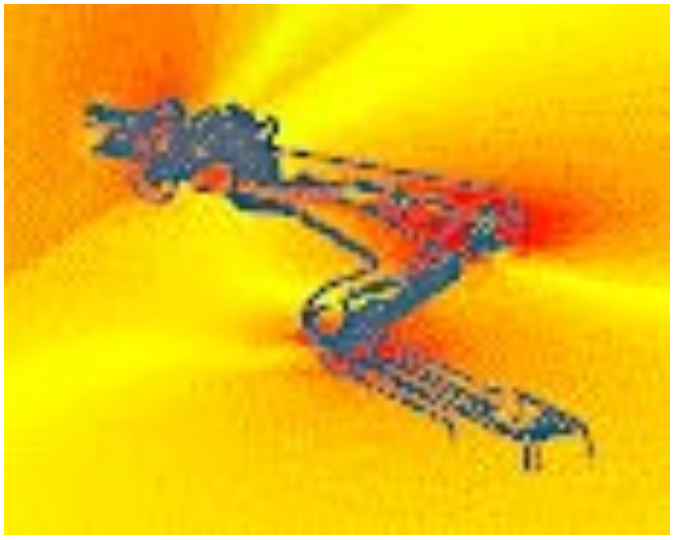
In addition to the simulation of structure-borne sound behavior, the radiation of airborne sound, excited by structural dynamics, is often of decisive importance. Elementary here is the development of components with a low degree of radiation for a given excitation, so that a local component vibration does not radiate any significant airborne sound. The simulation of the airborne sound radiation can calculate the sound pressure in the vicinity of the component or the total radiated sound power. For the subjective evaluation of virtual components in the sound studio, it is possible to filter real measurement data from the aggregate test bench via simulator-determined transfer functions to a virtual airborne sound and to support decision-making in product design by means of subjective perception.

Simulation hand in hand with experiment - mutual optimization at each iteration step

While the objective of new developments is usually based on previous models, real measurement data and their analysis, the development work usually starts with simulation. The aim is to select from various concepts the one that is most worthy of testing. Thus, the simulation allows the evaluation of components and concepts in advance, independent of time- and cost-intensive hardware.

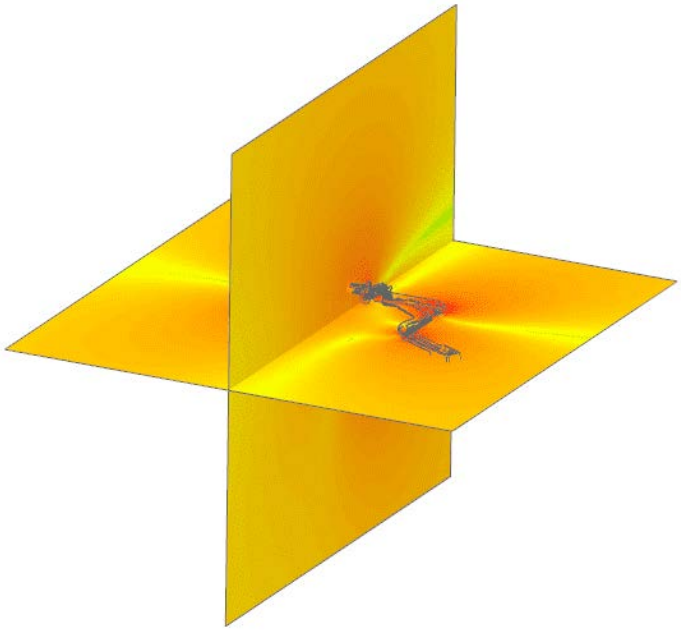
Throughout the further course of development, the close parallel management of simulation and testing enables constant mutual optimization. On the one hand, the quality of each hardware construction stage benefits from the previous simulation; on the other hand, the accuracy of the simulation models can be optimized by comparison with the subsequently available measurement data. Finally, the interaction of simulation and test embodies a maximum of target orientation and efficiency with regard to time and costs.

Simulated sound radiation based on structural dynamics



Component vibrations

The graph shows the maximum amplitudes of the vibration paths by superimposing the snapshots during the component vibration.



Radiation of airborne sound

The coordinate planes chosen here show the abstraction of airborne sound simulated on the basis of the above-mentioned component vibration (structural dynamics).
The areas of reduced radiation are conspicuous, recognizable by the yellow and green color areas.

VEHICLE TESTING

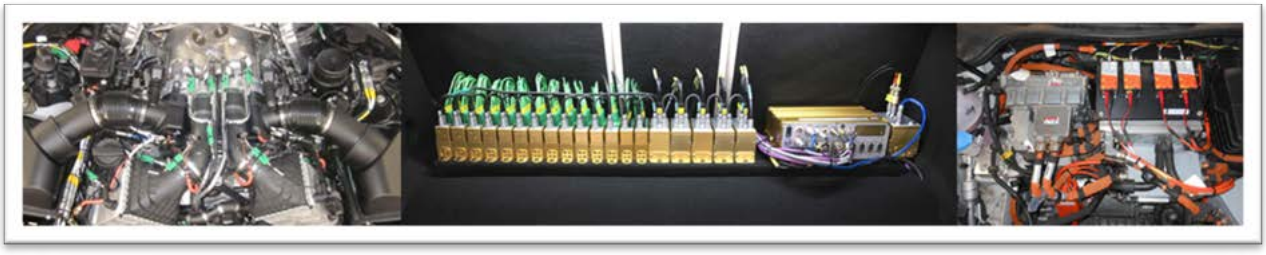
Vehicle upgrade

Starting with consulting and system procurement, we take over the entire project management. We install the measurement technology, including cabling and the complete application of sensors and actuators. Configuration and data evaluation are just as much part of the scope of services as calibration, functional testing and subsequent dismantling of the test vehicles. A modern technology center and an experienced team of application engineers and mechanics are available specifically for this purpose.

In the course of the steadily growing importance of hybrid systems and electric vehicles, we have developed our own high-voltage hardware solutions for current, voltage and temperature. These allow all relevant measured variables to be recorded via IPEmotion or our CAN bus data logger. They can also be integrated into existing CAN bus systems. In the context of the development of hybrid systems and electric vehicles, these are becoming increasingly important. Thanks to TÜV certification of our HV measurement technology as well as continuous further education and regular training in the high-voltage field, we guarantee the highest level of quality and safety. A separate area is available for the safe upgrade of electric and hybrid vehicles.

IPETRONIK services in vehicle upgrading

- Equipping vehicles with measurement technology and sensors (cars, trucks, vans, motorcycles, special vehicles)
- Sensor and measurement application of e-vehicles and HV components
- Complete solutions for measurement and application tasks
- Integration of various bus systems (CAN, LIN, XCP/CCP, Flexray, etc.)
- Special solutions
- Prototyping
- Complete project management

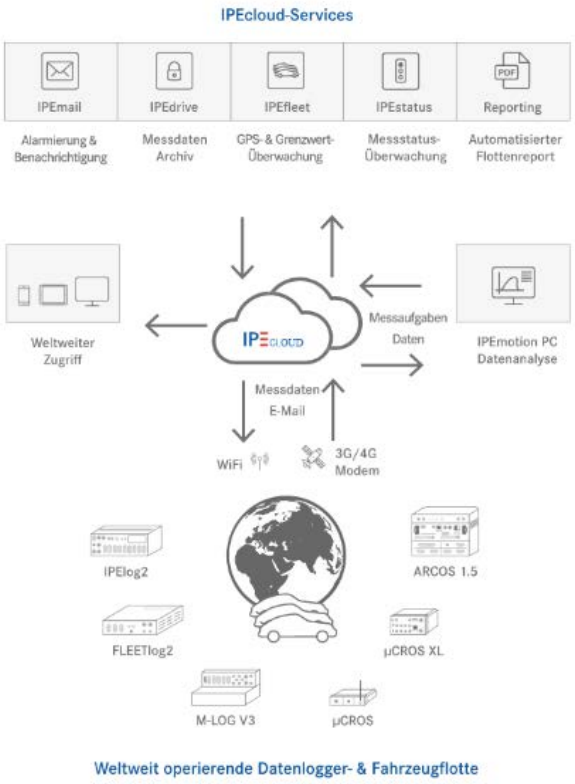


Vehicle endurance run and test support

Reliable, flexible and efficient worldwide

As a reliable partner with many years of experience, we offer all-round service in the field of vehicle testing. Our core competencies lie in the successful organization of vehicle and endurance tests. This includes planning, execution and analysis. In addition to testing under extreme conditions, we also carry out tests on individual components. In doing so, we always act according to our core values of efficiency, quality, adherence to schedules, flexibility and customer orientation. This enables us to meet even the most demanding requirements.

In addition to summer and winter tests, we also realize wind tunnel tests. Pre-selected we send all data for the involved departments directly to the PC of the project manager. We accompany our customers through the entire measurement project. In doing so, we ensure an error-free process, offer detailed data evaluation and generate meaningful test reports.



Whether in Germany or worldwide - we handle complete fleet projects. We plan, organize and supervise the vehicle endurance run and take care of the systematic design and tuning of the driving profiles. We provide daily status reports as well as fault analyses and have the possibility to carry out vehicle inspections, conversions and adjustments directly on site in our Technical Center. Our specialists have created an international infrastructure and use their experience from numerous projects. The entire logger fleet is centrally monitored and managed via our IPEcloud.

- Execution and supervision of tests at home and abroad
- Benchmark analyses
- Motor vehicle thermal inspections
- Special solutions
- Operational strength tests
- Prototyping
- Measurement data evaluation and documentation
- complete project management
- Long term fleet tests

Development carrier vehicles

Flexibility in measurements with simultaneous customer-oriented evaluation options

IPETRONIK offers its customers innovative options for the pre-development of refrigeration and coolant circuits, combining the advantageous features of a test bench setup with the flexibility of vehicle measurements: We build customer-specific vehicle subsystems in a vehicle body with extensive measurement technology. This allows system characteristics of new bodies to be experienced directly in the passenger compartment during measurement operation, which otherwise (as usual) only have to be interpreted on the basis of test bench measurement data. In addition, development carrier vehicles of this type can also undergo measurements in the climatic wind tunnel, on test tracks or in stationary operation. Our prototype workshop enables concepts to be realized at an early stage of development, when only a few components are available.

Design and measurements of development carrier vehicles

- Conceptual setups of prototypical subsystems in the engine compartment (e.g. in a body without engine)
- Innovative heat pump refrigeration circuits & concepts
- Construction of a real system based on conceptual designs of our customers
- High quality and appealing setups for customer internal research and management presentations
- Concept verification and functional proof through measurement operation
- Creation of characteristic diagrams for actuators within the system as a basis for control development
- Refrigerant circuit system optimizations - basic investigations and system adjustment
- Energy-autonomous setups for bridging measurement periods in mobile use, e.g. on a test track
- Interfaces to stationary power supply for long measurement periods without recharging

SPECIAL SERVICES

Leakage laboratory

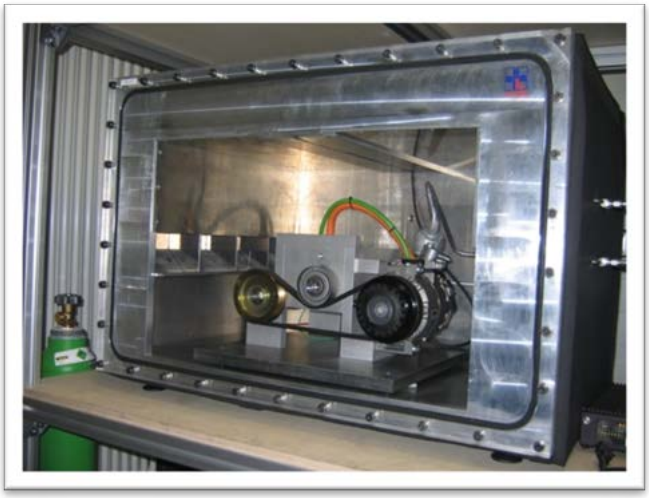
IPETRONIK is one of the few companies in Europe to have been accredited by the Federal Motor Transport Authority as a test laboratory for determining R134a leakage rates. The accreditation was granted on 20.12.2007 and was valid until October 2018, authorizing the company to carry out leakage measurements in accordance with Directive 2006/40/EC including Regulation 706/2007 on automotive air conditioning systems and their components within the scope of KBA type approval.

Since 2017, this type approval is no longer required by the KBA for air conditioning systems, as in Europe only new registrations of vehicles with a refrigerant with a global warming potential (GWP) <150 are permitted.

Ipetronik stands for environmental protection, because partially fluorinating greenhouse gases have not yet been completely eliminated, as vehicles with the refrigerant R134a are still on the roads. Here, too, the leakage rates of components must be kept as low as possible and the GWP must be reduced, for example, by using refrigerant mixtures.

Ipetronik has been operating the leakage laboratory since 2017 in order to continuously drive improvements in sealing concepts in the field of air conditioning and to detect faulty components at an early stage before they go into series production at the automotive manufacturer.

Ipetronik thus makes a decisive contribution to ensuring a high level of quality of the air conditioning systems and ease of service to the customer.



IPETRONIK leakage laboratory

- Leakage measurement according to Directive 2006/40/EC and Regulation (EC) No. 706/2007
- Preconditioning according to option 1 or option 2
- Leakage measurement on air conditioning systems
- Leakage measurement on air conditioning components
- Leakage measurement with temperature ramps
- Leakage measurement of different refrigerants
- Support in detecting large leaks or components to be improved/defective.
- Geodetic setup of the air conditioning system on site in the test laboratory

Technical data

Leakage chambers standard	
Temperature range	30 ... 50 °C
Print	Up to 160 bar absolute; Adjusts according to temperature and material data
Leakage chambers with changed general conditions	
Temperature range components	-20 ... 100 °C
Temperature range system chamber	-20 ... 50 °C
Pressure control	0-160 bar absolute via expansion tank
Realized via	
Climate acoustic chamber	
Espec air conditioner cabinet	

Example of a test cycle - test bench component chamber - refrigerant R744

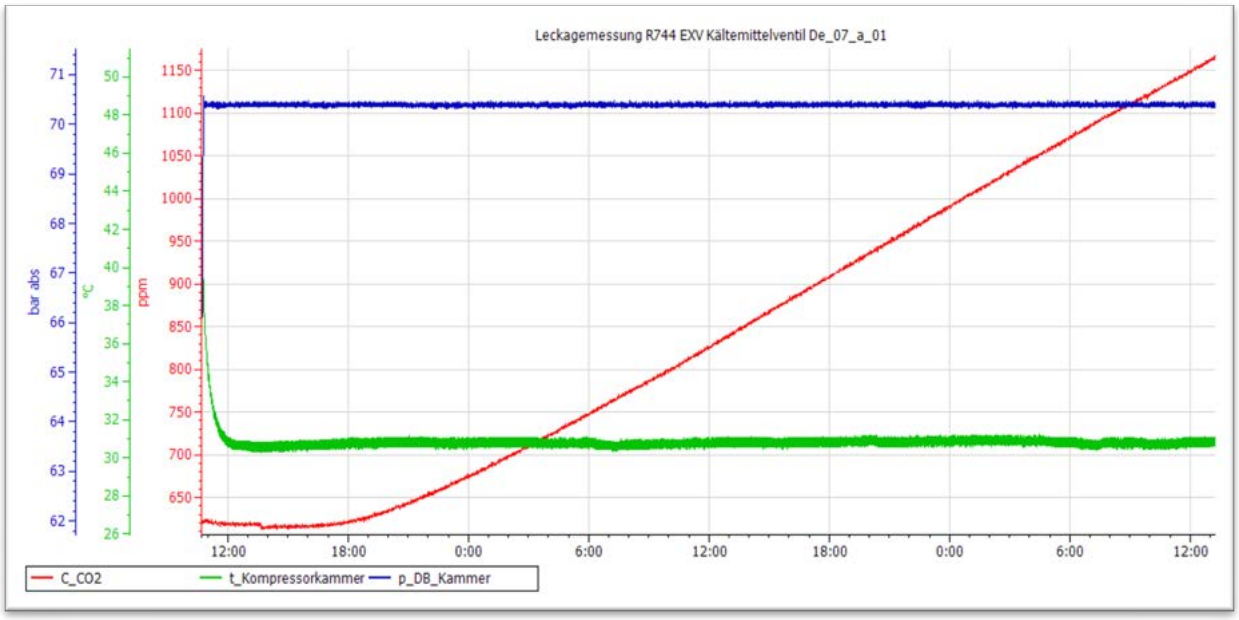


Figure 5: Measurement data: CO2 concentration in ppm (red), chamber temperature in °C (green) and system pressure bar abs. (blue)

Application examples

Leakage measurement according to Directive 2006/40/EC and Regulation (EC) No. 706/2007

z. E.g. Entire air conditioning system in the system chamber according to KBA type approval specifications. The system is set up and filled according to customer specifications. The measurement takes place at 40°C, the pressure adjusts itself according to substance data. Preconditioning over 20 days, measurement afterwards 24h. Refrigerant R134a for comparability and calculation with correlation factor.

Preconditioning according to option 1 or option 2

z. e.g. Option 1 -> 20 days preconditioning at 40°C, then the 24 h measurement; Option 2 -> 10 days preconditioning at 50°C + 1 day preconditioning at 40°C, then the 24 h measurement.

Leakage measurement on air conditioning systems

z. E.g. entire climate system in the system chamber is measured according to customer specifications or Ipetronik recommendation. The system is set up and filled according to customer specifications.

Leakage measurement on air conditioning components

z. e.g. valve block, air conditioning compressor or lines in the component chamber / fitting chamber. Measurement according to customer specifications or Ipetronik recommendation .

Leakage measurement with temperature ramps

e.g. measurement of an air conditioning compressor in the component chamber with temperature profile. This places a wide variety of stresses on the material, especially in combination with metals and rubber sealing lips. The aging process is accelerated and material tolerances are pushed to their limits.

Leakage measurement of different refrigerants

z. e.g. entire system in the system chamber. Comparability of the leakage of different refrigerants or refrigerant mixtures. Almost all common refrigerants in the passenger car sector can be detected or a new measuring filter can be generated.

Support in detecting large leaks or components to be improved/defective.

z. E.g. measurement of an air conditioning compressor in the component chamber. If an unusually high leakage is detected, we provide assistance in finding the component that is causing the large leakage. The same applies to complete systems or components of any kind.

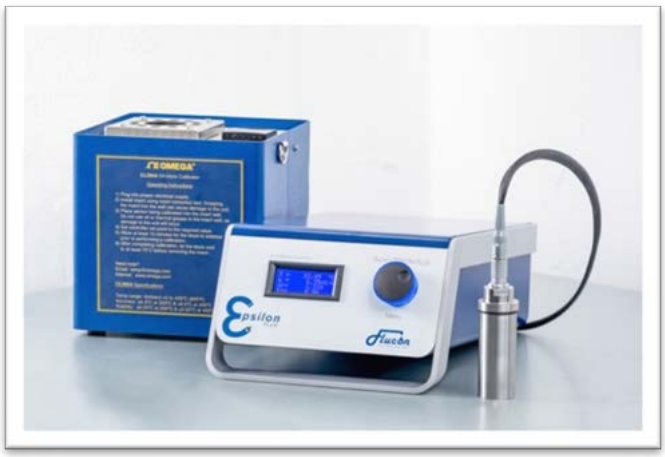
Geodetic setup of the air conditioning system on site in the test laboratory

This means that the refrigeration circuit is built on a rack according to customer specifications and CAD drawings. The structure thus corresponds to the position of the components as they are arranged in the vehicle.

Conductivity analysis of oils

Compressor development/testing

One of the state of the art topics in the development of electric refrigerant compressors is the analysis of the conductivity, or the influence, of the compressor oil on the stator windings and the associated insulation resistance. With the equipment shown in the picture, a sample can be analyzed automatically and evaluated with the help of the associated software.



IPETRONIK service conductivity analysis of oils

- Determination of the conductivity of the sample and the associated measured values:
  - Specific conductance κ in nS/m
  - Dielectric loss factor tanδ
  - Resistivity in Mohm*m
  - relative dielectric εr
  - Capacitance in pF
  - Resistance in Mohm
- Suitable for fluids with low electrical conductivity
- Digital acquisition of the measured values and control of the measuring device via associated software

Technical data

Measuring range	
Relative dielectric constant -Measuring range	1 ... 10
Specific electrical conductivity - Measuring range	0 nS/m ... 600 µS/m
Specific electrical conductivity - resolution	0.02 nS/m
Dielectric dissipation factor - measuring range	0 ... 10000
Dielectric dissipation factor - resolution	0,003
Measurement accuracy	+/- 1%
Temperature conditioning of the sample	30 ... 150°C

ISO-R Conductivity analysis of components and systems

In addition to the analysis of the compressor oil, the measurement of the insulation resistance is not only one of the technologically important topics, but also one of the safety and, conversely, product liability of a refrigerant compressor. Here, too, IPETRONIK positions itself centrally in the overall development of the main compressor component. In test methods or test procedures developed with customers, either the entire test item or only its stator is tested for insulation resistance.

IPETRONIK service insulation resistance measurements

- Determination of insulation resistance using the Sourcetronic ST2684A meter and associated software.
- Digital acquisition of the measured values and control of the measuring device via associated software
- Selectable measuring ranges, high voltage as well as current and resistance
- Selectable measuring time
- Current and resistance measurement

Technical data

Setting range high voltage	10 ... 1000V
Accuracy high voltage	2% from the reading value
Current limitation	2.25mA or 200mA
Current measurement	
Range 1	100µA ... 1mA / input impedance 10kΩ
Range 2	10µA ... 100µA / input impedance 10kΩ
Range 3	1µA ... 10µA / input impedance 10Ω
Range 4	100nA ... 100µA / input impedance 10kΩ
Range 5	10nA ... 100nA / input impedance 10kΩ
Range 6	1nA ... 10nA / input impedance 10kΩ or 1MΩ
Range 7	10pA ... 1nA / input impedance 10kΩ or 1MΩ
Resistance measurement	
Measuring range	10kΩ ... 100TΩ
Accuracy at measuring current >100pA	2%
Accuracy at measuring current <100pA	2% +/- Vtest/2pA
Dielectric dissipation factor - measuring range	0 ... 10000
Dielectric dissipation factor - resolution	0,003
Measurement accuracy	+/- 1%
Temperature conditioning of the sample	30 ... 150°C

Application examples

Insulation resistance measurement on the complete DUT or on the stator

Condensation test with insulation resistance measurement on the complete test specimen

Specification development support

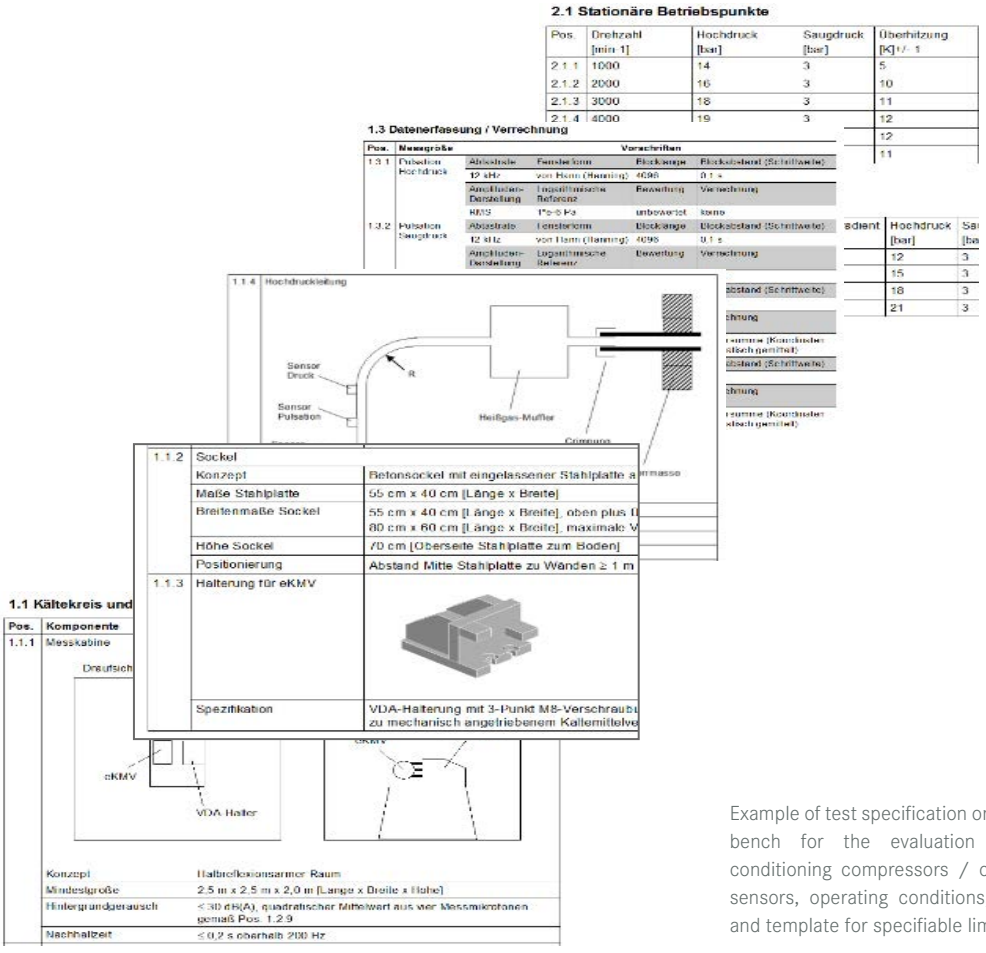
Concept development on the basis of measurement data, empirical values from vehicle tests, comparison with transfer path analyses, pilot test series on the aggregate test bench for new specification

In the development of passenger cars, testable vehicle prototypes are generally only available in the further course of the overall development period. Test specifications are therefore required for the new components and assemblies to be developed, which can be used independently of the vehicle on test rigs.

The targeting of such specifications is critical to the quality of the design level achievable in advance of all vehicle testing.

IPETRONIK has a wealth of experience in acoustic test methods for refrigeration circuits and the associated units and components. In the course of the past years, various specifications for electric and belt-driven air-conditioning compressors, among others, could be created.

The typical approach to conceptualizing a test specification starts with the installation situation of the unit in the target vehicle. In the case of unambiguous predecessor models, this derivation can usually be based on existing measurement data; in the case of completely newly designed vehicles, the derivation of the fundamentals requires additional steps based on simulations, on other comparison vehicles or on simple specifications.

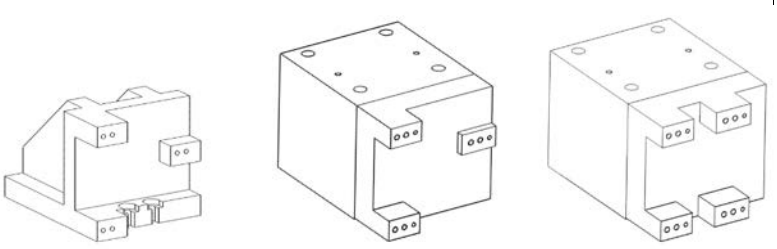


Example of test specification on acoustic unit test bench for the evaluation of electric air-conditioning compressors / contains structure, sensors, operating conditions, analysis method and template for specifiable limit values

IPETRONIK Service Methodical steps for specification development Acoustics

- Determination of acoustic behavior/limit values in the target vehicle
- Tracing of the transmission chains, starting from the target noise in the vehicle via the evaluation of sensitivities of the transmission behavior up to the permissible excitation by the power unit / validation by analyses of available measurement data or via simulation
- Definition of a set-up on the power unit test bench with vibro-acoustic measured variables at all relevant interfaces between power unit and vehicle (dyn. forces, vibrations, gas dynamics/pulsation, airborne noise) incl. customer-relevant operating conditions
- Pilot test series with units from predecessor vehicles to verify / optimize the new specification
- Final definition of test specification and limits after first application to new test items

Within the scope of specification developments for unit acoustics, it was also possible to establish certain standards at IPETRONIK. As a further development of the VDA holder for air-conditioning compressors with three M8 screw points, it was possible to derive a concept from a solid cube with exchangeable plates screwed to the rear. This allows compressors with a wide variety of new screw layouts to be installed on the test stand with extremely low resonance, so that the measurement of the dynamic forces can be performed with good reproducibility and with minimized test stand feedback.

Flexible aggregate holder for horizontal screw connection air conditioning compressor	
Compressor bracket (transverse screw connection)	 VDA 3-point Solid block 3-point Solid block 4-point

Likewise, the arrangement of large-dimensioned test bench mufflers (pulsation dampers) in the refrigerant lines has proven successful. Similar to the cross-sectional jump, e.g. at the condenser inlet in the vehicle, these mufflers exhibit a typical gas-dynamic impedance behavior.

In the area of general operating technology on the compressor test stand, an IPETROINK proprietary development was also established for acoustic testing: With the IPEload, which is available in variants for fluorine refrigerant and for CO2, steady-state and variable-speed compressor operation can be controlled and reproduced with high precision. Refrigerant pressures, temperatures, superheat and mass flow can be monitored and controlled.

Prototype store and special refrigerant pipe production

In the context of application and measurement tasks, it is sometimes necessary to design and manufacture special hardware solutions. In addition to experienced employees, a comprehensive range of machinery is available for this purpose.

IPETRONIK services in the field of

- Special solutions for refrigerant and cooling water lines
- Manufacturing interfaces for sensors
- Holder system manufacturing
- Glass refrigerant lines
- Modification of refrigerant components e.g. refrigerant compressor

Figure 6: Glass refrigerant line

Operational strength and application

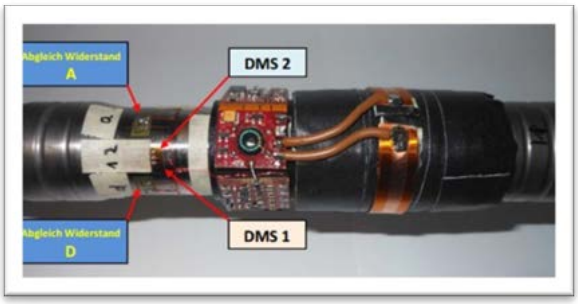
In our strain gauge laboratory we apply any kind of components. By means of strain gauges, we record a wide variety of parameters. With the information gained from this, we can make targeted changes to prevent material fatigue, for example. We also advise on the optimum positioning and calibrate the strain gauges and the complete measurement chain. Special torque applications including telemetry are also part of our services.

IPETRONIK services in the field of fatigue strength and application

- DMS application
- Torque measurement systems
- Telemetry
- Accelerometer
- Special solutions (e.g. strain gauge screw)
- Development of measurement systems (sensor, transducer, software and data management)

Application examples

Detection of torque on drive shafts Signal transmission via telemetry system



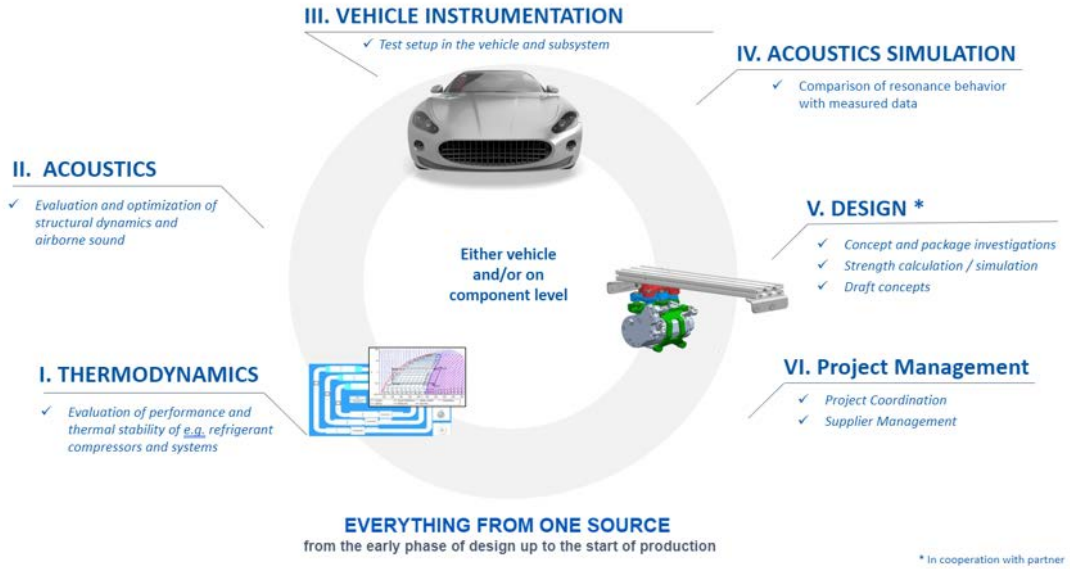
Recording of forces on tank straps by means of temperature-compensated strain gauge measuring points

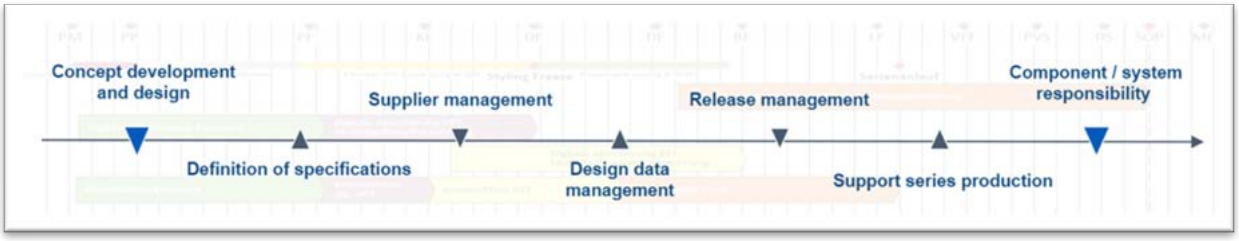
Detection of tensile and compressive load on tie rods

Automotive Project Management BTV

We have the competence to support your component or system in the development process from early concepts to series production and beyond.

Together with our partner ARRK Engineering, we can map the complete product development process. From design and simulation to testing and validation.





IPETRONIK Service Automotive Project Management BTV

- Holistic project support
- Consulting
- Project Management
- Data Management

Application examples

Development of refrigeration circuits & ventilation systems

We have already been able to prove our competence in the product development process at various OEMs and have successfully developed refrigeration circuits as well as ventilation and exhaust systems into series production. With a multi-supplier strategy, different refrigerants, diverse market requirements and ventilation systems with a high number of interfaces to other development teams, we do not shy away from high complexity. We also developed completely new acoustically optimized compressor bearing concepts for electric vehicles. Here, too, from design and simulation to validation.

References

- ASHOK Limited
- AUDI AG
- Automobili Lamborghini S.p.A.
- Bertrandt AG
- BMW AG
- Brabus GmbH
- DAF Trucks N.V.
- Daimler AG
- DEUTZ AG
- Dr. Ing. h.c. F. Porsche AG
- FCA Germany AG
- Ferrari S.p.A
- Ford Motor Company
- General Motors Company
- Hyundai Motor Deutschland GmbH
- IAV GmbH
- JAGUAR LAND ROVER LIMITED
- JATCO Ltd
- Kia Motors Corporation
- Liebherr-International Deutschland GmbH
- Mahindra & Mahindra Ltd.
- MAN Truck & Bus SE
- Maserati S.p.A.
- Mazda Motors GmbH
- Mercedes-Benz AG
- MODINE MANUFACTURING COMPANY
- NISSAN Center Europe GmbH
- Opel Automobile GmbH
- PEUGEOT DEUTSCHLAND GMBH
- Renault Deutschland AG
- Rheinmetall AG
- Robert Bosch GmbH
- ŠKODA AUTO Deutschland GmbH
- Tesla Inc.
- Volkswagen AG
- Volvo Car Corporation

IPETRONIK
AUTOMOTIVE ENGINEERING

Which project may we realize for you?

Arrange a meeting with one of our test bench specialists.

Simply send an e-mail to ipeeng@ipetronik.com

or by phone at +49 7221 9922 222.

We look forward to talking to you.

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