BioSpec/PharmaScan

Instructions for Use

Version 004

Innovation with Integrity

Preclinical Imaging

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1 About This Manual

The instrument is delivered with a System Owner binder that contains a USB stick with:

1. All relevant User Documentation such as for example instructions for use, safety, maintenance at the user level, contact etc.
2. This is complemented by the System Owner Manual with instructions and information for the System Owner (responsible body) to assist in fulfilling her/his responsibility for a safe operation of the instrument within the laboratory environment.
3. Also, Site Planning Information is provided that addresses persons who plan and prepare the instrument site. Such persons may include the System Owner as responsible person, but possibly also external planning agencies and engineers who are involved in the layout of the site and the realization of required site preparations.
4. In addition, a separate section MRI RF Coils is provided with RF coil specific information.

The System Owner binder also provides folders to file the different documents originating during the lifetime of the instrument. These are for example installation protocols such as the Magnet Field Acceptance, the installation Acceptance Protocol, training records, or service reports.

Before starting any work, personnel must read the manuals thoroughly and understand their contents. Compliance with all specified safety and operating instructions, as well as local work safety regulations, are vital to ensure safe operation.

The figures shown in the documentation are designed to be general and informative and may not represent the specific Bruker model, component or software/firmware version you are working with. Options and accessories may or may not be illustrated in each figure.

In addition, Bruker may provide the following listed documents that are not part of the accompanying documentation. These documents are designed for advanced users or special applications, and contain in-depth information beyond standard operation:

- **Software Manual**: Contains detailed information on the *ParaVision* user software for experienced operators, see the *ParaVision* Online Help.
- **Application Manual**: Contains detailed information and workflows for in vivo applications performed by experienced operators using the MR or PET/MR instrument with *ParaVision* software, see the *ParaVision* Online Help.
- **Programming and Administration Manual**: Contains detailed information on the application-specific programming of the MR or PET/MR instrument as well as hardware requirements for the workplaces and the scanner electronic. Information for workplace configurations, workplace networking and maintenance procedures are also provided. The document is addressed to method programmers and the instrument administrator, see *ParaVision* Online Help.

Service Documentation is not part of the delivery. Please contact Bruker Service & Life Cycle Support.

1.1 Symbols and Conventions

Safety instructions in this manual and labels of devices are marked with symbols.

The safety instructions are introduced using indicative words which express the extent of the hazard.

In order to avoid accidents, personal injury or damage to property, always observe safety instructions and proceed with care.

⚠ DANGER

DANGER: Indicates a hazardous situation that, if not avoided, will result in death or serious injury. This signal word is limited to the most extreme situations.

This is the consequence of not following the warning.

1. This is the safety condition.

▶ This is the safety instruction.

⚠ WARNING

WARNING: Indicates a hazardous situation that, if not avoided, could result in death or serious injury.

This is the consequence of not following the warning.

1. This is the safety condition.

▶ This is the safety instruction.

⚠ CAUTION

CAUTION: Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury.

This is the consequence of not following the warning.

1. This is the safety condition.

▶ This is the safety instruction.

NOTICE

NOTICE: Indicates information considered important, but not hazard-related (e.g. messages relating to property damage).

This is the consequence of not following the notice.

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SAFETY INSTRUCTIONS

SAFETY INSTRUCTIONS are used for control flow and shutdowns in the event of an error or emergency.

This is the consequence of not following the safety instructions.

1. This is a safety condition.

▶ This is a safety instruction.

This symbol highlights useful tips and recommendations as well as information designed to ensure efficient and smooth operation.

General Hazard

Sign indicating a general hazard.

Read the manual for safety instructions or action guidelines. Noncompliance with the information provided in the manual may result in hazards or incorrect operation.

Hazardous Electrical Voltage

Sign indicating hazardous electrical voltage.

Noncompliance with the safety instructions provided in the manual may result in serious hazards.

Radioactive Material or Ionizing Radiation

Sign indicating radioactive material or ionizing radiation.

Noncompliance with the safety instructions provided in the manual may result in serious hazards

Flammable

Sign indicating flammability.

Noncompliance with the safety instructions provided in the manual may result in serious hazards.

Biohazard

Sign indicating biohazard.

Noncompliance with the safety instructions provided in the manual may result in serious hazards.

1.2 Abbreviations

ACE	Animal Cell Extension
ATS	Animal Transport System
BMU	Bruker Magnet Monitoring Unit
CCM	Component Cabinet at the Magnet
DLHE	Dual Loop Heat Exchanger

EPU	Embedded Processing Unit
GC	Gradient Coil
GCTU	Gradient Control Temperature Unit
GTU	Gradient and Timing Unit
GPA	Gradient Power Amplifier
HMI Monitor	Human Machine Interface Monitor
LDU	Line (power) Distribution Unit
LPD	Line Power Distributor
RF	Radio Frequency
RFPA	Radio Frequency Power Amplifier
SPS	Shim Power Supply
TRX 1200	Transmit/Receive module broadband 1200 MHz
WAG	Waste Anesthetic Gas

Table 1.1: Abbreviations for AVANCE NEO based MR instruments.

2 Introduction

The BioSpec/PharmaScan MR instruments are part of a family of multimodal imaging instruments designed for various applications. BioSpec instruments can be extended to a combination of the MR instrument with an inline positron emission tomography (PET) instrument (PET/MR) or equipped with a PET insert. The electronic platform for the MR instrument is called AVANCE NEO.

Before initial operation, read all safety information and operating instructions given in this manual attentively and carefully, to ensure a safe and appropriate operation of the instrument.

2.1 Intended Use MR Instrument

Bruker MR instruments are research instruments for Magnetic Resonance Imaging or Magnetic Resonance Spectroscopy (MRI/MRS). The instruments are designed for in vivo investigations of laboratory animals and investigations of biological and non-biological samples.

The instruments are solely operated by trained users and under the control of the corresponding acquisition control and reconstruction software provided by Bruker.

The operation of MR instruments e.g. with strong magnetic fields are regulated by national laws of the country in which the instrument is operated. It is the responsibility of the system owner

- to follow these regulations.
- to assure that all users are well trained and familiar with all safety instructions before using the instrument.
- to assure safe working conditions for staff and any persons who might interact with the imaging device or with the regulated lab environment.

All Imaging experiments with laboratory animals must comply with the country-specific acts and regulations.

2.2 Contraindications

The use of the instrument is contraindicated for

- any examinations that are described by medical device regulations, e.g. MDD.
- any kind of in-vitro diagnostic (IVD) examinations that are described by IVD regulations, e.g. IVDD, IVDR.
- in-vivo examinations of humans or parts of the human body.

2.3 Normal Operating Conditions

For a safe operation of the instrument, it must be operated under Normal Operating Conditions.

This includes compliance with environmental conditions (see System Owner Manual Environmental Conditions) as well as:

- The device is for indoor use only.
- Cooling water (and compressed air for PET option) provided and operational.
- Quench Pipe installed and operational (not required for cryogen free magnets).
- Magnet supervision installed and operational.
- All doors and covers of the instrument and the cabinets are closed.
- The door of the Faraday cage and/or of the CCM are closed.
- RF coils intended for use are connected and loaded either with a dedicated sample or phantom.
- The instrument is READY without indication of error messages.
- No electrical or protective grounding modifications of the instrument.
- No mechanical modifications of the instrument.

2.4 Performance Environmental Conditions

In order to achieve the specified performance of the instrument, the enhanced performance environmental conditions in the different areas of the installation must be met, for example enhanced temperature stability conditions in the magnet and technical room are required beyond the environmental conditions for a safe operation. The full set of requirements for the performance environmental conditions are given in the Site Planning Information.

Operational Qualification within the specifications of the instrument can only be obtained when the performance environmental conditions are fulfilled.

3 Overview

The MR instrument consists of the following functional components:

- **Magnet and shims** to generate a strong and homogeneous spin polarization.
- **Gradient fields** to decode the spatial distribution of the spins.
- **Radio frequency RF Coils** to trigger and detect the signals.
- **Scanner control electronics**, high power electronics and chiller.
- **Animal handling accessories**, i.e. anesthesia, animal beds and supervision devices.

These components are located at different sites within the laboratory, refer to the figure below.

- **the magnet room:** Magnet, gradients, RF Coils and animal handling devices
- **the operator area:** Acquisition control and data evaluation workplace
- **the technical room:** Scanner control and high power electronics, chiller

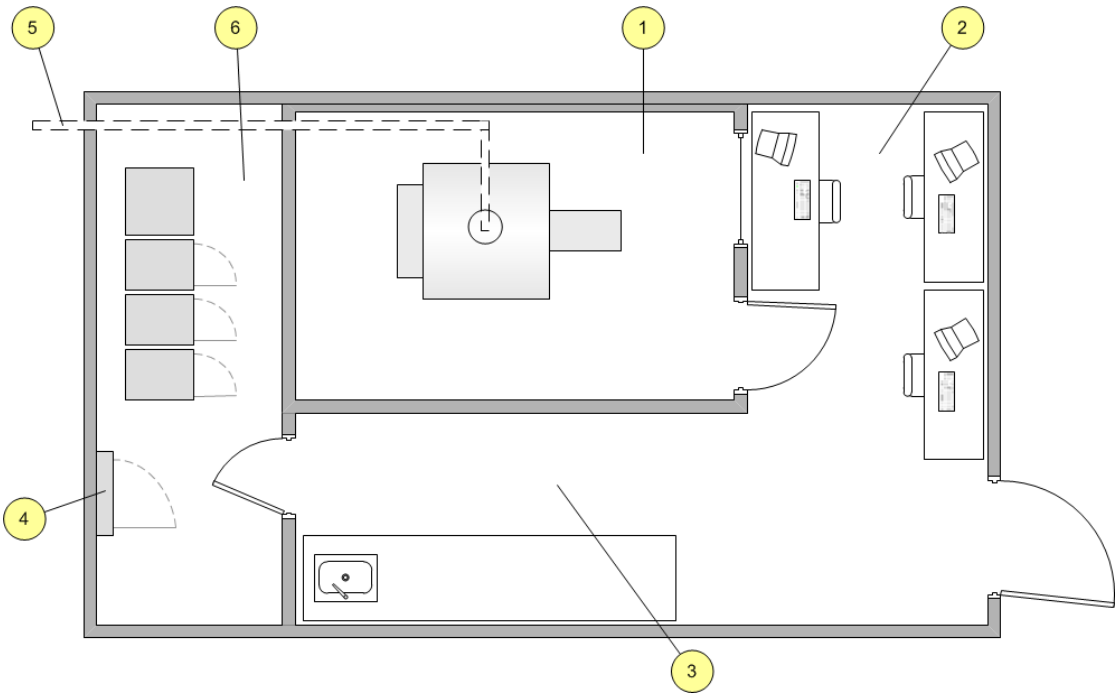

Figure 3.1: Schematic laboratory ground plan

Pos. No	Description
1	Magnet Room
2	Operating Area
3	Preparation Area
4	Electrical Power Distributor
5	Quench Line
6	Technical Room

4 Safety

4.1 Introduction

This chapter covers safety issues when operating the instrument. It is required that every user is familiar with the safety aspects given in this chapter.

Please note that additional information is given in the following manuals:

- Safety aspects regarding the laboratory infrastructure and regulatory compliance are given in the System Owner Manual. This is in the responsibility of the System Owner (responsible body).
- Safety aspects regarding site planning, transport, rigging, or moving the instrument are given in the Site Planning Information.
- Safety aspects for Bruker Service are given in the corresponding documents of the Service Documentation.

Warnings and safety instructions are assigned as follows. The keywords indicate the level of hazard involved.

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4.2 General Safety Information

Instruments described in this manual are subject to the safety demands given by the low voltage directive. Electric safety is proven by the application of the safety requirements for electrical equipment for measurement, control and laboratory. According to these regulations, no part accessible under the condition of a single electrical fault is hazardous to human life.

⚠ WARNING

Danger of injury from electrical shock.

A life threatening shock may result when housings or cabinet doors are opened and covers or components are removed while connected to the line power.

Only authorized and electrically qualified personnel should carry out work.

▶ Switch instrument/component OFF and disconnect from line power.

▶ Prevent reconnection.

▶ Test for absence of harmful voltages.

⚠ CAUTION

Risk of Fire

Ensure a general prohibition of smoking or open fire in the area where the instrument is installed. For MR instruments, this applies to the Controlled Access Area and in the technical room.

▶ For MR instruments, only non-magnetic fire extinguishers equipped with carbon-dioxide are to be used in the Controlled Access Area.

4.3 Access to the MR Instrument

4.3.1 Controlled Access Area

The Controlled Access Area is the three-dimensional area in which the magnetic field strength is 0.5 mT and higher. It is defined by the 0.5 mT magnetic stray field line of the magnet. The contour maps of the magnetic stray field are provided in the System Owner Manual.

System owner or authorized personnel must ensure that individuals entering the Controlled Access Area must put down all loose ferromagnetic objects and must be questioned about their medical history (e. g. with respect to pace-makers, surgical implants, metal splinters, etc.).

Individuals with implants (e.g. cardiac pacemakers, clips, prostheses, etc.) are not allowed to enter the Controlled Access Area and pass beyond this 0.5 mT contour line.

It is the responsibility of the system owner to inform all users about applicable national and local regulations and occupational standards.

⚠ WARNING

Risk of personal injury or death due to effects originating from strong magnetic fields.

Entering the Controlled Access Area bears various risks that can lead to serious injuries. People with medical implants or pacemakers must not enter the Controlled Access Area.

- ▶ Refuse and prevent actively people carrying medical implants entering the Controlled Access Area.
- ▶ Refuse and prevent actively non-authorized and or non-trained personnel entering the Controlled Access Area. Inform visitors on the potential risk originating from the high magnetic field. Do not leave visitors unattended.
- ▶ Be familiar with the extension of the 0.5 and 3 mT region within the Controlled Access Area.
- ▶ Always reflect and be aware of the potential risks when entering the Controlled Access Area. Accidents occur often by being unthoughtful or careless during routine work in the Controlled Access Area.
- ▶ It is good practice to establish a standard procedure when entering the Controlled Access Area and depose all personal accessories outside that might be affected or become dangerous projectiles.

⚠ WARNING

Risk of personal injury or death

The magnetic field of the superconducting magnet remains on even when the MR instrument is powered off.

- ▶ All safety measures associated with the Controlled Access Area have to be observed even when the MR instrument is powered off.

The following warning and prohibition signs are attached at the entrance of the Controlled Access Area.

Meaning of warning signs at the entry of the Controlled Access Area

	Strong magnetic fields
	High frequency fields
	Hearing protection

Meaning of prohibitions signs at the entry of the Controlled Access Area

	No entry for persons with cardiac pacemakers, defibrillators, hearing aids, insulin pumps, dosage devices for medication
	No entry for persons with metallic implants and other metal objects in the body
	Do not enter with any ferromagnetic devices such as keys, coins, watches, pocket calculators and mobile phones
	Do not enter with ferromagnetic objects like fire extinguishers or pressure gas cylinder
	Do not enter with any ferromagnetic devices such as medical instruments of all types
	Data carriers, such as credit cards, memory sticks, hard drives and identity cards might be damaged
	Do not enter with ferromagnetic tools of any kind
	Do not enter with ferromagnetic charts or trolleys of any kind

NOTICE

Malfunction of laboratory equipment sensitive to magnetic fields

Within the Controlled Access Area, the MR instrument can

1. interfere with electronic devices so that they might not work as intended
2. be influenced by electronic devices so that image quality can be affected

▶ Always check accessories located in the Controlled Access Area for MR compatibility.

Exposure to magnetic fields

It is recommended not to stay inside the magnet room during MR scans. In case specific experiments require personnel to stay close to the magnet for prolonged time while scanning or preparing experimental setups, ensure compliance with occupational standards (worker protection).

NOTICE

iPhone 7 or higher becomes temporarily unusable or even damaged.

New iPhone generations (from iPhone 7 up) are very sensitive to environments with increased Helium concentrations and can become temporarily unusable or even damaged.

1. In addition to the risk of damage by the magnetic field, increased He concentrations may occur in the Controlled Access Area or during service activities.

▶ Leave mobile phone outside the Controlled Access Area.

▶ Especially during service actions of charging/discharging the magnet or filling He, mobile phones need to remain outside areas where He concentration may become increased.

▶ In case of problems with the iPhone, follow the corresponding instructions in the iPhone User Manual.

4.3.2 Exposed Area

The exposed area is the three-dimensional area in which the magnetic field strength is between 0.1 and 0.5 mT. It is defined by the corresponding stray field lines of the particular magnet types. The exposed area is not a general area of risk.

NOTICE

Malfunction of laboratory equipment sensitive to magnetic fields

Within the Exposed Area, sensitive equipment may still experience impairment of functionality, disturbance, or defects.

4.4 ON/OFF Switches and Mains Disconnect

Prior to working with the MR instrument, familiarize yourself with the function and location of the ON/OFF switches and the Mains Disconnect.

ON/OFF Switches

The MR instrument has two types of ON/OFF switches:

- Electronic ON/OFF switch to switch the instrument electrically OFF.

- Magnet Emergency Quench Button to rapidly discharge the magnet.

Mains Disconnect

In addition, a Mains Disconnect is located at the Line Power Distributor (LPD) to disconnect the instrument from mains. The LPD is typically located on the Technical Area close to the electronic cabinets. Ensure that access to the LPD is always granted.

Figure 4.1: Line Power Distributor with Mains Disconnect.

4.4.1 Electronic ON/OFF Switch

The Electronic ON/OFF Switch is intended to switch on/off the electrical power of all electronic components of the MR instrument. However, the ON/OFF Switch does not affect the magnet and the magnet supervision.

The Electronic ON/OFF Switch is installed at an easily accessible location close to the operator console. Every user should be familiar with the position of the switch. It is recommended to check in regular intervals the free access to the switch.

In case of emergency, the main power of the instrument can be switched off immediately using this Electronic ON/OFF Switch.

1 Electronic ON/OFF Switch. In case of emergency, turn the switch anti-clockwise to power off the MR instrument.

4.4.2 Magnet Emergency Quench Button

The Magnet Emergency Quench Button is intended for de-energizing the magnet within a few seconds to minutes in emergency situations caused by the magnetic field. An emergency applies whenever there is danger for a person to be injured due to the action of the magnetic forces, and there is no other solution than an emergency quench of the magnet. This might for example be the case when a person is squeezed and held against the magnet by a large ferromagnetic object. The force might be so high that it is impossible to remove the object and free the person without first de-energizing the magnet.

All personnel must be clearly instructed how to use the Magnet Emergency Quench Button and to use only in case of emergency.

Normally, there are two Magnet Emergency Quench Buttons installed; one in the magnet room, and one at the magnet supervising unit in the electronic cabinet. Every user should be familiar with the positions. Keep free access to the buttons.

⚠ CAUTION

Risk of personal injury.

If the magnetic field is switched off by the Magnet Emergency Quench Button, a magnetic object that had been attracted to the magnet will fall down when the field is discharged. This may cause subsequent injuries.

▶ Potentially support the object or take precautions against subsequent injuries.

1 Magnet Emergency Quench Button at the magnet supervising unit located either in the dual loop heat exchanger cabinet or in the high power cabinet in the technical room of the MR instrument.

2 Magnet Emergency Quench Button normally installed close to the magnet inside the magnet room.

4.5 Static and Electromagnetic Fields

The MR instrument consists of several components that produce various electromagnetic fields and a very high static magnetic field. Electromagnetic radiation may cause harm to the operator as well as affect the surrounding environment. The following topics will be addressed:

- Static magnetic field: The magnet provides a strong time-invariant magnetic field called static magnetic field.
- Gradient fields: Time-dependent magnetic fields.
- Radio frequency fields: RF coils driven by RF power amplifiers produce pulsed high frequency electromagnetic fields.

4.5.1 Static Magnetic Field

The static magnetic field is generated by a super-conducting magnet. The US, USR and US/R type of magnets are equipped with active shielding to minimize the magnetic field in the outside and the surrounding of the magnet (ultra-shielded magnets). The static magnetic field is highly homogeneous in the magnet bore and drops considerably fast to low magnetic fields outside the bore. The magnetic force that acts to ferromagnetic parts is proportional to the change of the magnetic field strength. In regions, where the magnetic field strength decreases considerably within short distances, the force on ferromagnetic parts can be very

strong. As a consequence, such objects become hazardous projectiles, especially in front of the magnet bore. It is an illusion to think that ferromagnetic parts can be handled in a safe way in front of a magnet bore!

⚠ CAUTION

Dizziness when moving the head at the entrance of the magnet bore

Do not move your head at or close to the entrance of the magnet bore. A temporary feeling of drowsiness, dizziness, or metallic taste may result. These effects become stronger the faster the movements are.

NOTICE

Potential damage of devices by strong magnetic field.

The magnetic field can

1. erase magnetic data media, e.g. disks, memory sticks, credit cards
2. destroy mechanically-sensitive components, e.g. watches, hearing aids, cameras

▶ Always check accessories that shall be used within the Controlled Access Area for compatibility with magnetic fields.

⚠ WARNING

Risk of personal injury or death by projectiles

Ferromagnetic objects introduced into the vicinity of the magnetic field become projectiles. Especially in front of the bore, such objects cannot be controlled and become life-threatening projectiles.

▶ No ferromagnetic material may be brought into the vicinity of a MR magnet. If it is unclear if a device contains ferromagnetic material, do not use in the vicinity of the magnet until compatibility has been proven. Always be aware of the strong and sudden attractive force on ferromagnetic materials mainly at the entrance of the magnet bore.

▶ Do not wear or carry ferromagnetic objects on your person or in your pockets, for example watches, pens, scissors, …

▶ Do not use gas tanks as for example oxygen, nitrogen, or helium tanks within the Controlled Access Area.

▶ Do not use ferromagnetic cleaning tools in the Controlled Access Area.

▶ Be especially cautious with sharp or massive objects, i.e. scissors, knives, needles, tools, or non MR compatible animal accessories.

▶ Never examine samples that contain ferromagnetic materials.

⚠ CAUTION

Risk of injury and or severe damage of the magnet

Accidentally attracted ferromagnetic material stuck in the magnet may be only removed without risk of injury or damage to the system when discharging the magnet. Contact your local Bruker Service.

NOTICE

Risk of injury or death of the animal, destruction of samples

Ferromagnetic or electrically-conductive materials inside the sample or object under investigation (i.e. aneurysm-clips, prostheses, shrapnel, metal splinters, needles,...) may dislocate due to the extreme forces exerted by the magnetic field. This may result in severe internal injuries or destruction of the sample.

- ▶ No animals/samples carrying ferromagnetic implants may be brought into the Controlled Access Area.

4.5.2 Gradient Fields

Faraday's law establishes a relationship between the changes of a magnetic field over time and electrical fields. Therefore, switching gradient fields induces an electrical field in conducting material or tissue. Resulting eddy currents can heat materials or tissue. In vivo, also peripheral nerve stimulation may result due to shifts of charges dissipating the resting membrane potential of the nerve fibers.

When the gradient coil is used at a high gradient duty cycle, the inner surface of the gradient coil can heat up and remain hot for some time.

Read and follow the warnings listed below when operating the MR instrument. Prior to use of accessories within the gradient field, read section Accessories below.

⚠ CAUTION

Risk of burns

The magnetic fields created in the Gradient Coil (gradient fields) can cause burns when running MR scans.

- ▶ Do not enter the gradient field with your extremities while running MR scans.
- ▶ Do not bring conducting material into the gradient field since it heats up.
- ▶ Do not touch the surface of the Gradient Coil or the RF Coil while or shortly after running MR scans since the surface might be hot.

⚠ CAUTION

Peripheral nerve stimulation

Fast switching magnetic fields created in the gradient coil (gradient fields) can cause nerve stimulation.

- ▶ Do not enter the gradient field with your extremities while running MR scans.

NOTICE

Risk of short circuit because of condensate

Setting the cooling seed point of the gradient cooling water below 18°C or inappropriate environmental conditions increase the risk of water condensation.

- ▶ Operate the instrument in the environmental conditions specified in the System Owner Manual or in the Operating Instructions (where applicable).
- ▶ Do not regulate the temperature of the gradient cooling water below 18 ºC.

NOTICE

Harm to the animal by increased body temperature

High gradient duty cycle and fast gradient switching schemes applied for a long duration lead to high temperatures at the inner surface of the gradient coil. Depending on the animal setup and the remaining air circulation, a lethal heating of the animal can occur. In case of scanning animals with high gradient slew rates, be aware of potential nerve stimulations in the animal.

- ▶ We recommend to use an animal monitoring system to monitor vital signs (for example heart rate, respiratory rate, body temperature, …).

4.5.3 Radio Frequency Fields and RF Coils

Under normal operation conditions no risk to the operator arises from the usage of Bruker RF Coils and accessories. Nevertheless, the following safety aspects need to be considered.

Exposure of tissue to radio-frequency electromagnetic fields generated by the RF Coils can cause significant tissue heating.

RF coils and accessories that are not tested and released by Bruker for compatibility with the MR instrument bear a potential risk.

⚠ CAUTION

Risk of burns

RF power deposition in tissue (specific absorption rate) or touching RF contacts can lead to local burns while the MR instrument is scanning.

- ▶ Do not approach, touch or enter with your extremities the RF Coil while scanning.
- ▶ Do not use RF Coils with damaged housing or damaged cables.
- ▶ Do not remove covers from RF Coils.
- ▶ Do not disconnect or remove RF Coils while scanning.

NOTICE

Risk to damage RF Coils

RF Coils are sensitive, mainly to mechanical shocks.

- ▶ Only trained people are allowed to handle RF Coils.
- ▶ Handle RF Coils with great care.
- ▶ Avoid mechanical shocks to the housing.
- ▶ Do not overwind the tuning or matching rods.
- ▶ Do not use RF Coils in different positions or with different loadings than intended.

NOTICE

Risk to damage receive-only coils

Receive-only coils that are not correctly connected to the socket(s) or coils that are used with wrong coil configuration are possibly not detuned while the transmission coil is in operation. They absorb large portions of the transmission coil's RF power and may get damaged.

- ▶ Ensure that coils inside the transmission coil are correctly connected to the socket.
- ▶ Ensure that the correct coil configuration is selected.

NOTICE

Electromagnetic Interference / Risk to Damage Electronic Devices / EMC compliance.

The application of strong RF pulses might lead to unwanted interference with or physical damage of electronic devices in a common electromagnetic environment. The Electromagnetic Compatibility (EMC) standard may be violated.

- ▶ To avoid such situations, the instrument must be used under the Normal Operating Conditions as defined in the System Owner Manual.
- ▶ While scanning, all doors of the instrument, all doors of the cabinets, the cover of the animal transport system or the Faraday cage (where applicable) must be closed. Corresponding sealing must be regularly maintained.

NOTICE

Harm to the animal by increased body temperature

The maximum allowed RF power limit of a RF Coil is a technical limitation of the coil and might be considerable higher than the maximum RF deposition dose that can be applied to living samples (specific absorption rate – SAR).

- ▶ Bruker recommends to use an animal monitoring system to monitor vital signs (for example heart rate, respiratory rate, body temperature, …).

4.6 Acoustic Noise

Fast gradient switching schemes result in acoustic noise during MR scans. Especially ultrafast sequences may result in significant acoustic noise levels and therefore represent a potential risk to the operator.

⚠ CAUTION

Risk of hearing damage

Fast gradient switching causes significant noise pressure levels.

▶ Do not stay within the magnet room during MR scans without hearing protection.

When in vivo animal experiments are performed, be aware of acoustic effects on the animal. Many animals are very sensitive to sound and have a different acoustic hearing spectrum than humans.

NOTICE

Harm to the animal by hearing damage

Be aware of the acoustic noise and potential hearing damage of the investigated animals while scanning.

▶ It is recommended to use hearing protection for animals while scanning.

4.7 Injury by Mechanical Effects

The hazard of tripping is in particular related to unfavorable routing of cables or hoses of accessory devices. Make sure that this risk is minimized by appropriate routing.

⚠ WARNING

Risk of tripping

▶ Route cables and hoses of accessories like anesthesia gas tubes, water tubes of the animal warming, or supervising equipment to prevent tripping over.

The doors of cabinets and Faraday enclosures have EMC shielding contacts made out of elastic copper springs. The springs can bend with time or even break and become then a possible source of cutting damage. Replace any broken or bended springs.

⚠ CAUTION

Blade injury, laceration

Bended or broken EMC shielding springs are a source of blade injury or laceration.

▶ Replace broken or damaged springs of the RF shielding.

4.8 Accessories

Under normal operating conditions no risk to the operator arises from the usage of Bruker accessories. Accessories that are not tested and released by Bruker for compatibility with the instrument bear a potential risk.

Some accessories require specific handling as listed in the sections below.

⚠ WARNING

Danger of injury from electrical shock.

1. Defective devices or devices having insufficient safety standard bear the risk of electrical hazard.

- ▶ Use only devices and line power cables with approval by nationally recognized testing laboratories (NRTL).
- ▶ Do not use defective devices or cables or devices showing safety relevant signs of wear and tear.
- ▶ Check the water hoses and connections before using them in the imaging instrument (where applicable).
- ▶ Do not use leaking devices in the imaging instruments.

⚠ CAUTION

Risk of personal injury and environmental damage

In case water, for example from the Animal Body Temperature Conditioning water circuit or from the Animal Warming Blankets is spilled and potentially entered the RF Coil (MR instruments), safety measure have to be followed to dry up the instrument in a safe way. In case of spills other than water e.g. from samples containing chemicals or radioactive tracers, see section Removal of Spilled Sample Fluids or section Radioactive Tracer and Samples where applicable.

- ▶ Stop running scans and switch the scanner to the stand-by mode.
- ▶ Dry all wet surfaces and devices of the MR instrument using a dry cloth.
- ▶ Then, where applicable for RF Coils: Remove the RF Coil from the instrument and allow spilled water to flow out of the coil by placing it in a suitable manner.
- ▶ Ensure that all wet areas were dried before switching the instrument on again or using the RF Coil. If unclear, let the instrument dry afterwards for an appropriate time, potentially for several hours.

4.8.1 Battery Pack and ERT Module

The battery pack and ERT module of the animal monitoring device from SA Instruments must not be used within the gradient or RF field since they may overheat.

Locate the ERT module at the rear of the animal cradle which does not extend into the gradient / RF field. For the battery pack, different lengths of cables are provided in order to locate the battery pack at an appropriate distance.

⚠ CAUTION

Risk of burns or fire due to overheating of the battery pack.

The battery pack and ERT module of the animal monitoring device from SA Instruments Inc can be used within the static magnetic field. However, very fast switching gradients can heat the battery pack and ERT module due to eddy currents induced.

- ▶ Locate the battery pack and ERT module such that it will not be within the gradient and RF coil (examples of gradient coils, see below).
- ▶ We recommend to validate the MR protocol in combination with the locations of the battery pack and ERT module initially prior to long term use: Run the protocol for 1-2 minutes, stop the scan and check surface temperatures of the battery pack and ERT module immediately. In case you detect a warming up of a module, position the module further outside and repeat the test. Otherwise, repeat the test with increased scan duration until a safe use of the modules can be guaranteed without noticeable warming up over the entire protocol duration.

How to identify the location of the gradient or RF field?

At most instruments, you will identify the gradient coil looking into the magnet bore from the animal table side. The gradient coil itself will start at the rim where the diameter of the bore decreases. Some instruments use a smaller gradient coil within the larger one (gradient insert), so that you will detect two rims. Furthermore, inside the gradient coil, the RF coil is located.

Two examples are given below. In case you cannot identify the gradient or RF coil at your instrument, please contact the hotline.

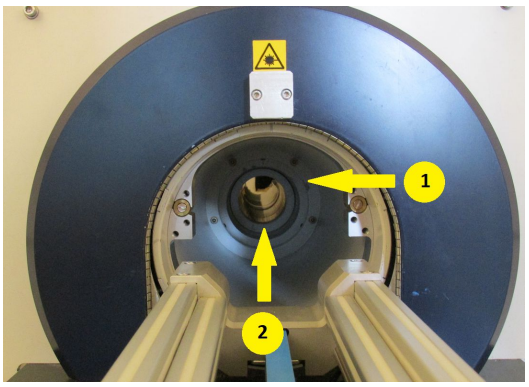
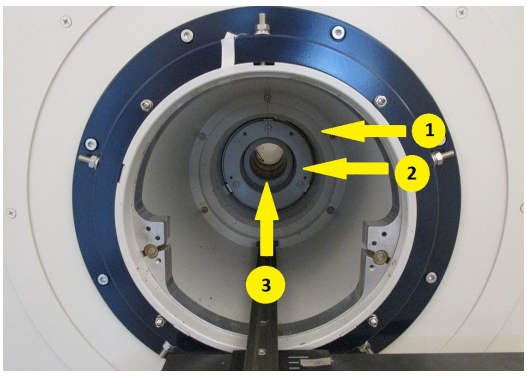
	
1 Gradient Coil 2 RF Coil	1 Gradient Coil 2 Gradient Insert 3 RF Coil

Table 4.1: Examples to identify the gradient and RF coil within the magnet bore. View facing the instrument front at the animal table.

4.9 MRI Samples

4.9.1 Handling and Storage of Samples

All Bruker imaging samples for operational qualification/quality assurance of the MR instrument (sometimes called “QA phantoms”) are designed under the aspect of harmless chemical composition and safe operation. Therefore, no risk to the operator arises from the usage of those samples under normal conditions. A small residual risk to the operator cannot be avoided especially with leaking or broken sample containers.

⚠ CAUTION

Risk of personal injury

Depending on the chemical sample composition, sample fluids become a potential risk to the operator.

This may happen when a sample container is broken, when it is spilling, or when refilling the sample.

- ▶ Read the Material Safety Data Sheet (MSDS) prior to handling samples and follow the instructions therein. For Bruker samples MSDS can be downloaded from the Bruker website.
- ▶ Handle samples with great care.
- ▶ Wear suitable eye and skin protection.
- ▶ Avoid any contact between the sample fluid and the skin or eyes.
- ▶ Do not swallow sample fluids.
- ▶ Store and use samples only under the enhanced environmental conditions at room temperature.
- ▶ Do not refrigerate or freeze Bruker samples.
- ▶ When used in MR scans, avoid intense RF power deposition that can possibly heat up the sample fluid and burst the sample container.

⚠ CAUTION

Risk of Fire

- ▶ Store and use flammable samples only at ambient room temperature.
- ▶ Do not store samples at locations with direct sunlight. It is a potential risk of fire due to the lens effect.

4.9.2 Removal of Spilled Sample Fluids

Spilled sample fluids bear potential risks to the operator and must be completely removed from the MR instrument. The spilled fluid needs to be handled and disposed in compliance with local regulatory and safety.

⚠ CAUTION

Risk of personal injury and environmental damage

When fluids are spilled, safety measure have to be followed to clean up the instrument in a safe way.

- ▶ Stop running scans and switch the scanner to the stand-by mode where all high power devices are disabled.
- ▶ Read the Material Safety Data Sheet (MSDS) and follow the instructions therein. For Bruker samples MSDS can be downloaded from the Bruker internet presentation.
- ▶ Wear suitable protective clothing to avoid skin or eye contact with sample fluids or broken glass.
- ▶ Wear a mask with a filter for inorganic vapors if aerosols are formed.
- ▶ Do not swallow sample liquids.
- ▶ Clean all spoiled surfaces and devices of the MR instrument and let it dry afterwards for several hours.
- ▶ Absorb the fluid using absorbent material such as sand, sawdust, etc. and prevent sample fluid from entering the waste water system.
- ▶ Store them in a labeled and suitable container for disposal.
- ▶ Dispose them according to local regulations.
- ▶ Clean your hands thoroughly using soap and water.
- ▶ Change contaminated clothing.

4.9.3 First Aid in case of contact with Sample Fluids

The reaction to unwanted sample fluid contact depends on the chemical composition of the sample. The composition of Bruker QA samples is indicated on the label of the sample. Therefore, first read carefully the label.

In addition, the corresponding Material Safety Data Sheets (MSDS) are given in the accompanying documentation of the MR instrument or the delivery of the sample. There is also a download section in the Bruker internet presentation.

Follow the instructions given in the MSDS. General recommendations are given below:

In general it is recommended to consult a physician immediately after first aid.

Skin contamination:

- Immediately remove the clothing covering the contaminated area.
- Immediately wash the skin using soap and water.

Eye contamination:

- It is recommended to consult an ophthalmologist.

Swallowing:

- Drink plenty of water and induce vomiting immediately.

Swallowing of oil:

- Do NOT induce vomiting.
- Ensure that the person lies still.

Inhalation:

- Leave the building immediately to get some fresh air.

4.9.4 Material Safety Data Sheets

Material Safety Data Sheets (MSDS) of the Bruker samples can be downloaded from *Bruker MSDS*.

Search by part number of the phantom or sample fluid.

4.10 Cryogen Liquids

In order to keep the inner temperature of the magnet low enough to maintain supra-conductivity, the magnet is filled with liquid helium (magnet types US and USR) and liquid nitrogen (magnet type: US, only). If the inner temperature of the magnet increases above a certain threshold, the magnet is going to quench. This can be caused by low levels of cryogen liquids.

During normal operation, the USR type magnet does not lose any relevant amount of helium. Following special conditions like power failure, malfunctions of the cold head or maintenance activities, liquid helium has to be refilled by the Bruker Service. All work at the magnet including filling of helium is considered a service action and must therefore be performed by other persons than trained Bruker Service.

During normal operation of US type magnets, the helium and nitrogen levels decrease by evaporation with time. In adequate intervals, the cryogenic liquids must be refilled. All work at the magnet including filling of helium and nitrogen is considered a service action and must be performed by trained Bruker Service.

Properties of liquid helium and liquid nitrogen:

- Extremely low temperature:
  - Helium: - 270 °C
  - Nitrogen: - 190 °C
- Oxygen in ambient air is displaced during boil-off
- Odorless
- Non-flammable
- Non-toxic

⚠ WARNING

Risk of severe personal injury or explosion

- ▶ Only Bruker Magnet Service may perform work on the magnet.
- ▶ Do not open or remove any safety valves and/or burst disks of the magnet dewar.

⚠ WARNING

Risk of asphyxiation or severe burns by cryogen liquids

The handling of cryogen liquids bears potential risk of severe personal injuries like burns or asphyxiation. Rapidly escaping helium or nitrogen as it occurs during the filling process of a magnet can possibly displace the air in the magnet room and can therefore be a potential risk for asphyxiation.

- ▶ Only authorized and trained personnel may refill cryogen liquids.
- ▶ Always have a second person supervising from outside while handling liquid cryogens.
- ▶ Wear suitable protective gloves and eye protection.
- ▶ Use only non-magnetic dewars and carts.
- ▶ Store cryogen liquids in sufficiently ventilated rooms only.
- ▶ No humans are permitted inside an elevator (or any other insufficient and closed room) that hosts dewars with cryogen liquids.

⚠ CAUTION

Risk of fire by condensation of oxygen

Helium and nitrogen are non-combustible. However, oxygen in the room may condense at the quench line or into relief ports and vents which are in contact with liquid helium. If these fittings are coated with flammable oils and grease, a potential fire hazard exists.

- ▶ All flammable material must be removed from the immediate vicinity of the magnet.

4.11 Anesthesia

Many in vivo experiment are performed with narcotic gases. Narcotic gases can have a negative impact on the operator. Read the Safety Data Sheets of the different narcotic gases and follow the instructions therein.

Different animal containments can be use during measurements. Depending on the type of the animal cradle, Waste Anesthetic Gas (WAG) can be removed from the cradle and/or the anesthesia mask. Nevertheless, the chamber or mask cannot be considered as fully air tight. Thus, a portion of anesthesia gas can escape.

In any case, follow the warnings given below.

⚠ CAUTION

Health hazard by anesthesia gas above regulatory limits (worker protection)

Compliance with occupational safety and health regulations are in the responsibility of the System Owner (responsible body). Acute exposure to Isoflurane as well as chronic exposure can cause health hazard.

1. Anesthesia gas delivered into the instrument can escape.

▶ Use corresponding air suction in the surrounding enclosure where applicable.

▶ Use Waste Anesthetic Gas suction from the anesthesia mask where applicable.

▶ Operate instrument in a room with sufficient air exchange rate.

▶ To ensure safe and adequate handling of anesthesia, only trained and authorized users may work with anesthesia gas. Repeat training on a regular base.

▶ Check residual anesthesia gas concentration to stay within worker protection regulatory limits (for example using regularly gas personal monitors suitable for Isoflurane detection).

⚠ CAUTION

Risk of Fire

Anesthesia gases may be flammable.

▶ Use non-flammable gases (e.g. isoflurane).

NOTICE

Death of or harm to the animal

1. The Bruker instrument is often used in combination with anesthesia devices (Trade Products) that deliver anesthesia gas. Overdose of anesthesia gas might cause the death of the animal. It is in the operators responsibility to monitor vital signs of the animal.

▶ We recommend to use an animal monitoring system to monitor vital signs (for example heart rate, respiratory rate, body temperature, …).

▶ Follow the instructions for use of all device suppliers such as for example the anesthesia device or animal monitoring trade product supplier.

▶ Ensure operation of vital signs when preparing the experimental setup. For example check ECG wires and hoses of respiratory air pressure pad for blockade.

5 Switching ON/OFF the Instrument

The MR instrument can have the following operating states:

Operating State	Description
System OFF	The entire instrument electronic is deactivated. The MR instrument is not ready for use. It cannot be switched on by the ParaVision software. Magnet water cooling circuit and magnet refrigerator are active. • Use this operation status, when the MR instrument is not used for a long period of time, e. g. during holiday.
STAND-BY	Same as System OFF but communication and line power control is operational so that the instrument can be switched on by the ParaVision software. In addition, the water cooling of the gradient coil is operational to maintain thermally stable condition within the magnet bore. • Use this operation status, when the MR instrument is not used for a short (manageable) period of time, e. g. overnight or during the week end.
System ON	The entire instrument electronic is active. The MR instrument is ready for use.

5.1 Changing the Operating State (Remote Electronic Switch)

Change the operating state of the instrument at the Remote Electronic Switch as follows:

<table>
<tr><td>1</td><td colspan="2">Get the ParaVision workplace ready of use and start ParaVision.</td></tr>
<tr><td>2</td><td rowspan="2"> 
</td><td>Switch System ON:
• Turn the rotary switch (1) clockwise in ON position.
• Press the ON button (3) briefly and wait until the signal light lights up green permanently.
– The instrument is now ready for use.</td></tr>
<tr><td>3</td><td>Switch System to STAND-BY:
• Press the STAND-BY button (2) briefly and wait until the signal light at the ON button (3) changes from green to orange.
– The instrument is deactivated and not ready for use (stand-by).
Note: You only need to press the ON button (3) briefly again to switch back to the operating state »System ON«.</td></tr>
<tr><td>4</td><td colspan="2">Switch System OFF:
Turn the rotary switch (1) counter-clockwise in OFF position.</td></tr>
</table>

You can switch interactively between the operating states STAND-BY and ON using the *ParaVision* software. Proceed as follows:

▶ Click the ON/OFF button (1) in the *ParaVision* control bar to switch between STAND-BY and the operating state ON.

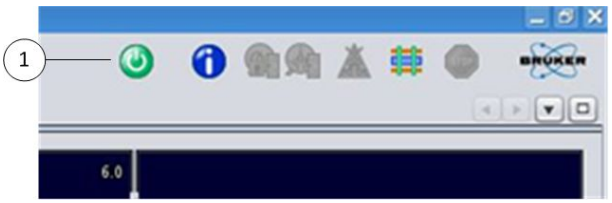


Figure 5.1: ON/OFF button in the ParaVision control bar.

5.2 Electric Emergency

In case of an electric emergency, for example electric shock or short circuit, proceed as follows to put the instrument out of operation:

1. Turn the rotary switch (1) at the Remote Electronic Switch counter-clockwise in OFF position. The instrument is powered off immediately.
2. Turn the Mains Disconnect at the Line Power Distributor (LPD) counter-clockwise to OFF to disconnect the instrument from mains.

Figure 5.2: Line Power Distributor with Mains Disconnect.

NOTICE

The magnetic field and the supervision of the magnet remains ON when switching the MR Instrument OFF.

1. The Electronic ON/OFF Switch (Remote Electronic Switch) switches off all electronics but the magnetic field, the water cooling circuit of the magnet and the magnet supervision.
2. The Mains Disconnect at the Line Power Distrubutor (LPD) disconnects the instrument from mains. However, the strong magnetic field remains.

▶ In case of emergency with regard to the strong magnetic field, use the *Magnet Emergency Quench Button [▷ 21]*.

Further information on the different ON/OFF switches, see chapter *Safety [▷ 15]*.

Switching ON/OFF the Instrument

6 Operating Area and ParaVision Software

The instrument is controlled almost completely by the *ParaVision* software, that means, the acquisition control, data reconstruction, data evaluation and data archiving are controlled by correspondent software functions. Compatible software version is *ParaVision* 360 and newer versions. Older versions of *ParaVision* cannot be used.

6.1 MR Acquisition Workplace

The acquisition workplace contains a Linux based host computer, a 24'' full HD and high image contrast monitor as well as peripheries like mouse, keyboard and optional printer, see the following figure.

Figure 6.1: ParaVision workplace with peripheries (without printer).

Beside standard I/O ports, the host computer is equipped with two Ethernet ports. One is solely attributed to the communication with the MR instrument, the other is attributed to set up external networks.

The host computer is equipped with 64 GB RAM. Only for very high end applications, the workstation may require more RAM. In this case, please contact your local Bruker office.

NOTICE

If RAID system, PCI boards and RAM upgrades are not installed properly, the computer hardware and/or the operating system can be damaged.

The Installation of additional memory or PCI boards requires sufficient qualification of computer hardware handling and the Linux operating system.

- ▶ Do not install additional components such as PCI boards or RAM without consulting Bruker. In case of contraventions you will lose the warranty of the workstation.
- ▶ Only qualified personnel authorized by Bruker may perform installation.

6.2 ParaVision Software

The ParaVision software package is pre-installed and configured by Bruker according to the hardware upon delivery of the instrument. Purchased licenses are pre-installed and operational. After purchasing licenses later on, please contact Bruker Service how to enable these licenses on the instrument.

NOTICE

Unauthorized alteration of the software configuration can decrease the instrument's performance or even damage the instrument.

- ▶ Do not modify the configuration of the installed ParaVision Software. Contact the Bruker Service in case of doubt.
- ▶ Only use the original Bruker acquisition workstation.
- ▶ Do not install other than Bruker released software on the host computer.
- ▶ Do not install additional packages, patches or bug fixes.
- ▶ Avoid excessive networking while scanning.

NOTICE

Alteration of *Base Level Acquisition* parameters from outside the PVM method framework can damage the instrument hardware irreversible.

- ▶ Only experienced users should change the *Base Level Acquisition* parameters in the single parameter editor.
- ▶ Pay special attention to stay within the given hardware limits.

NOTICE

Alteration of *Base Level Acquisition* parameters from outside the PVM method framework can cause wrong image data and image display labelling: This may be for example:

1. wrong image geometry, for example left-right interchanged,
2. wrong image dimensions, for example the sample appears larger or smaller than in reality,
3. wrong flip angles, for example different contrast,
4. etc.

▶ Only experienced users should change *Base Level Acquisition* parameters in the single parameter editor.

▶ Verify your modifications and results prior to general usage.

6.2.1 ParaVision Concepts: User and Operator

ParaVision is designed as a multiple user/operator application. Each user can have multiple operators. Any user data (MR data, protocols, scan programs, RF coil configurations, methods, etc.) is solely attributed to the user that is currently logged in into the application. However, this date is accessible for all operators that are using the same user account.

The user data are private per default. ParaVision provides the functionality to publish private user data and import them to other users. The pre-installed default user in ParaVision is »MR User«. In most cases all operators in a laboratory use the same MR User account. The Datasets are labeled with the name of individual operator. If for privacy reasons multiple users are required to protect user data from unauthorized access, additional users can be created and used.

In order to prevent unwanted damage of the scanner configuration, certain program features that relate to the configuration of the software are password protected. The password is requested every time when such a feature is started. The system administrator is responsible to set up an adequate policy within the group of users/operators.

6.2.2 ParaVision Concepts: General Workflow

The generalized ParaVision workflow includes the four steps shown below:

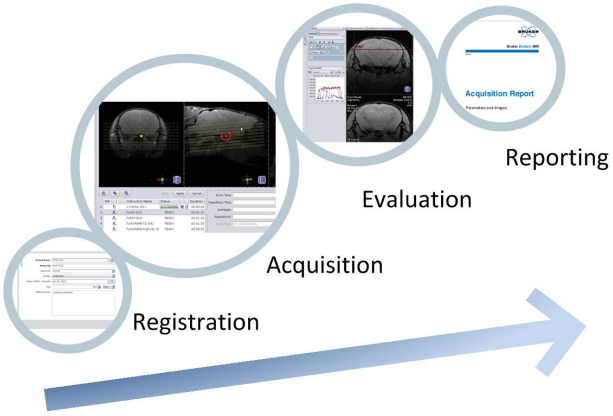


Figure 6.2: Sequence of the ParaVision workflow

- During the registration a subject is assigned to the planned study possibly within a project.
- Data acquisition (and reconstruction) is done based on predefined protocols and scan programs.
- The reconstruction and evaluation can be performed either manually or automated.
- Parameter, images and results of an experiment are summarized in acquisition reports.

6.2.3 ParaVision Concepts: PET/MR Workflow

ParaVision 360 is the main user interface for the operation of the PET/MR instrument. It is used for acquisition control of PET and MR image data, image reconstruction, image co-registration and fusion, numerical and visual evaluation and data archiving. Depending on the hardware generation of the MR instrument, the MR image acquisition is either controlled by the same ParaVision 360 workplace, or if the MR hardware is not supported by ParaVision 360, the acquisition is done from a former ParaVision version such as 6.x or a later version and is then imported per drag & drop into the ParaVision PET/MR workplace.

Figure 6.3: (*) with AVANCE III HD MR electronics platform or older versions, ParaVision 6.0.1 or newer is used to acquire the MRI data. In these installations, both ParaVision versions are running in parallel on the same PET/MR workplace.

6.2.4 ParaVision Concepts: Application cards

ParaVision is a multiple cards (also called tabs) software application with the following main applications:

- **EXAM card:** The EXAM card is the main application window to setup and acquire studies. Via the interface of the EXAM card, protocols and scan programs can be selected and edited, and scheduled in the automatic scan program queue. For the setup of protocols, method specific user interfaces are offered. The geometry editor is integral part of the EXAM card and allows defining interactively the desired scanning geometry basis on reference images. The EXAM card is opened using a previously prepared study via the Exam action in the DATASET BROWSER, or directly after the registration of a new study.

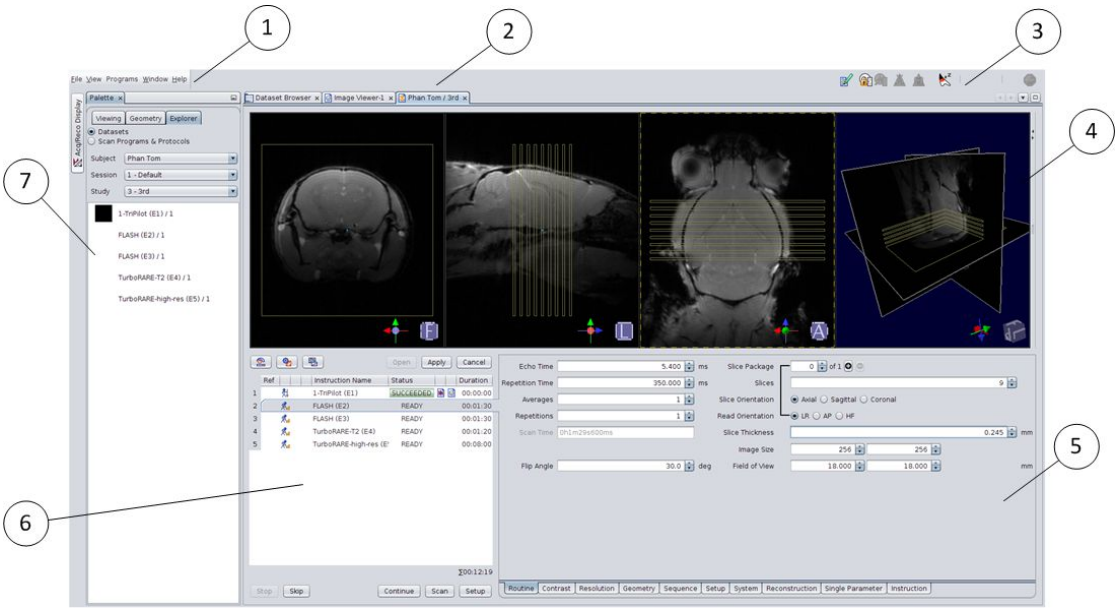


Figure 6.4: EXAM Card interface.

Pos. No	Description
1	Main menu bar
2	Application card tabs
3	Scanner and software status bar
4	EXAM card: Geometry editor
5	EXAM card: Protocol editor
6	EXAM card: Scan program table
7	EXAM card: Protocol Palette

- **VIEWING card:** The VIEWING card is the main application window for the presentation and analysis of 2D and 3D images. Using the VIEWING card, multiple images can be displayed and selected based on selected image criteria of multi-parametric image series simultaneously. Image properties such as the displayed image regions, color maps, zooming and shifting are directly accessible by small toolbars in every viewport. For data analysis, region of interest (ROI), profiles and different numerical evaluation tools are offered. The VIEWING card appears by double-clicking on a completed image series dataset in the DATASET palette or the DATASET browser. Multiple VIEWING cards can be opened simultaneously. The image series dataset can be dropped from any ParaVision application on the tab of an opened VIEWING card.

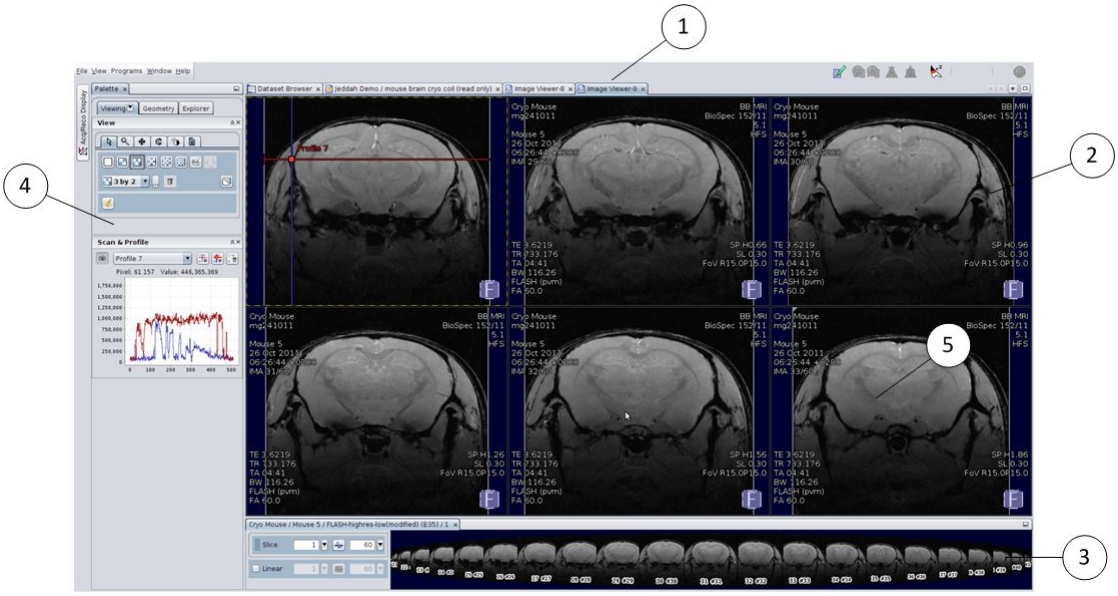


Figure 6.5: VIEWING Card interface.

Pos. No	Description
1	Multiple instances of the view card.
2	Image viewport
3	Image series slide show.
4	VIEW card palette, showing the menu for Scan & Profiles functionality.
5	Single image

- **DATASET Browser:** Within ParaVision, datasets, protocols and scan programs are organized in a database. The DATASET browser is a powerful tool to manage these data. It allows searching for specific keywords, tags, preferences or text strings on different hierarchical levels. Depending on the selection of certain (subsets) of data, different actions can be executed on the data, including archiving and retrieval of data on a network computer cluster.

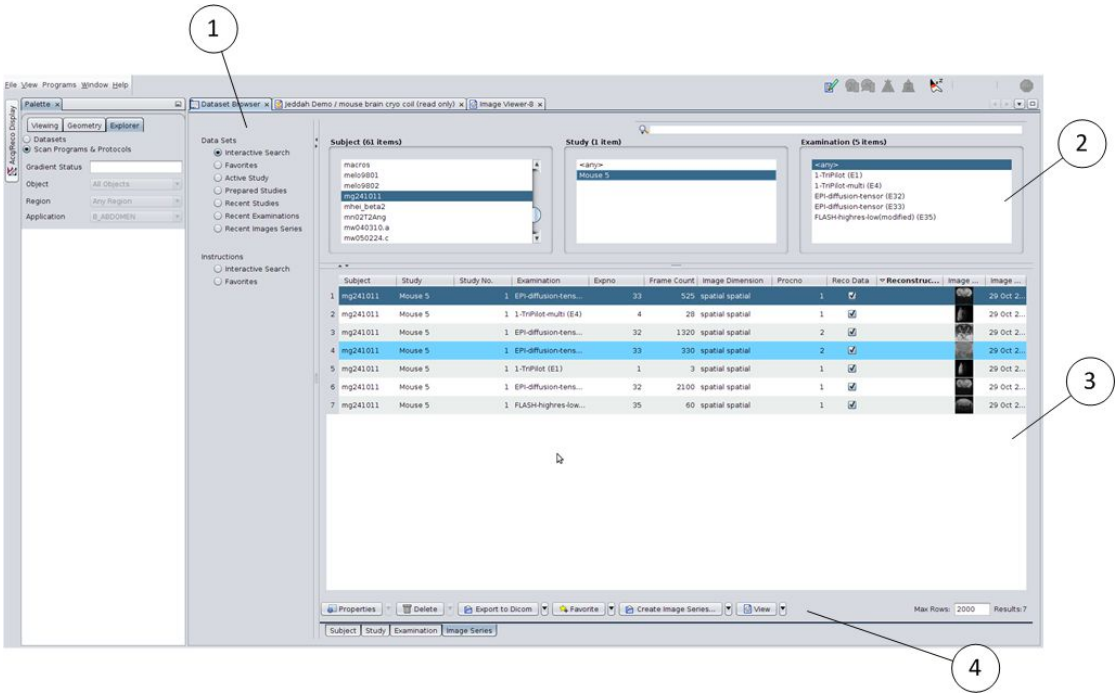


Figure 6.6: DATASET Browser interface.

Pos. No	Description
1	Quick find with presets (e.g. favorites, recent studies).
2	Query based on hierarchical structures.
3	Query result of data sets.
4	Context-dependent actions on selected data sets.

6.2.5 ParaVision Concepts: Hierarchical structure of data and protocols

Image data is organized in a hierarchical structure that relates to the following levels:

1. Project (optional)
2. Subject
3. Session (optional)
4. Study
5. Examination
6. Images Series

Protocols and scan programs are organized in a hierarchical structure that relates to the following levels:

1. Object
2. Region
3. Application

6.2.6 ParaVision Concepts: Multiple ParaVision workplaces

Several processing workplaces can be connected to the main ParaVision acquisition workplace in the following manner:

- Data can be transferred and evaluated on dedicated processing workplaces.
- Projects, Subjects, Studies and Examinations can be prepared independently from the actual usage of the ParaVision acquisition workplace. Once defined, they can be transferred to the acquisition workplace.
- Data can be transferred to processing workplaces and archived to commonly used archive media and servers.

6.3 ParaVision Online-Help

The *ParaVision* Online Help (ParaVision User Manual) is an integral part of the *ParaVision* software and can be accessed online via the ParaVision Help menu:

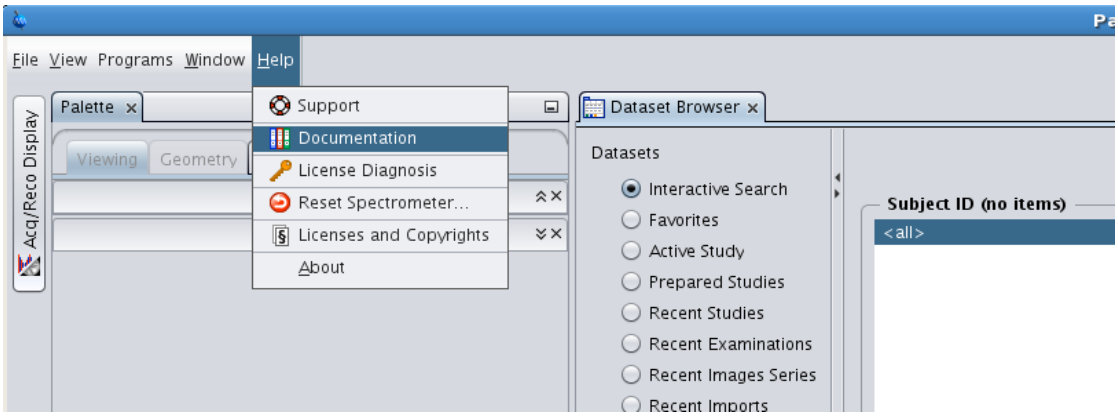


Figure 6.7: Help menu within the user interface

The *ParaVision* Online User Manual is divided in three topics:

- **Software Manual:** This documentation describes all software features, software workflows and provides a detailed description of all measurement methods and parameter
- **Application Manual:** This documentation describes Workflow and is the Reference documentation for application issues such as the cardiac imaging on mice and rats.
- **Programming and Administration Manual:** This documentation describes data formats, software configuration and method programming.

6.3.1 Starting ParaVision

▶ After the host computer has started, perform the following steps to start the *ParaVision* software.

1. Log into the host computer.
   Enter the user and the corresponding password in the login shell and confirm.
   ➨ The pre-installed ParaVision standard user is called »nmr«. The password is documented in the Acceptance Protocol of your instrument.
2. Start the ParaVision software by double-clicking the ParaVision icon on the desktop of the workstation.

6.3.2 Starting the Online Help

The *ParaVision* Online Help (ParaVision User Manual) is an integral part of the *ParaVision* software and can be accessed online via the ParaVision Help menu:

1. Start ParaVision as described in section *Starting ParaVision [▶ 47]*.
2. Open the Help menu in the menu bar and select Documentation.

6.3.3 Printing the ParaVision User Manual

If required you can print the *ParaVison* User Manual using the print functionality of the PDF Viewer.

7 Magnets

7.1 Magnet Types

Depending on the configuration, the MR instrument is equipped with one of the following superconducting magnet types:

- **USR magnet type:** The ultra-shielded and refrigerated magnet technology is a zero-boil-off instrument with pulse tube cooler and minimized external fields. These magnets contain liquid helium, but no nitrogen. The used refrigeration technology prevents that the liquid helium vaporizes by continuously recycling. Therefore, the helium has not to be refilled.
  The service interval of these magnets is limited to maintaining the coldhead. All servicing work on the magnets must be performed by the Bruker Service.
  Typical magnets using this technology: 47/40 USR, 70/20 USR, 70/30 USR, 94/20 USR, 94/30 USR, 117/16 USR.

- **US/R magnet type:** The ultra-shielded/refrigerated magnet technology has a pulse tube cooler and minimized external fields. These magnets contain liquid helium, but no nitrogen.
  The used refrigeration technology minimizes the vaporized helium. Therefore, the liquid helium has to be refilled once a year. The service interval of these magnets is limited to maintaining the coldhead.
  All servicing work on the magnets must be performed by the Bruker Service.
  Bruker recommends refilling the liquid helium by the Bruker Service, but trained and authorized laboratory personal could also refill.
  Typical magnets using this technology: 94/11 US/R, 117/11 US/R, 152/11 US/R.

- **US magnet type:** The ultra-shielded magnet technology has minimized external fields. These magnets contain liquid helium and liquid nitrogen. The liquid helium has to be refilled once a month. The liquid nitrogen has to be refilled once a week.
  All servicing work on the magnets must be performed by the Bruker Service.
  Bruker recommends refilling the liquid helium by the Bruker Service, but trained and authorized laboratory personal could also refill.
  Typical magnets using this technology: 47/16 US and 70/16 US.

7.2 Magnet Operation

7.2.1 Quench Tube

All magnets listed above must be attached to a gas-exhaust pipeline, also called a quench tube. The quench tube is needed to sustain the safe operating condition in case the magnet status changes unplanned from superconducting to normal conducting. In this process, the magnet will be discharged by it's own very rapidly. This is called "the magnet quenched".

Under normal operation conditions, the quench tube is blocked to the magnet dewar by a burst disk. This burst disk brakes as soon as the magnet quenches and the quench tube vents the quickly evaporating cryogen gases out of the magnet room to the outside of the building.

NOTICE

After a quench, there is a risk of condensate formation or re-sublimation of air inside the magnet dewar.

After a quench contact as soon as possible the Bruker Magnet Service and ask for replacement of the broken burst disk as soon as possible.

The magnet is located on U-shaped beams, which are supported by vibration absorbers to minimize influences from building vibrations. Therefore, thee quench tube is also mechanically isolated using a flexible quench tube connection. In the following figure a quench tube connection is shown as an example.

Figure 7.1: Quench tube connection in the magnet room.

Pos. No	Description
1	Quench tube
2	Magnet dewar, containing liquid cryogens
3	Stand with vibration dampers

7.2.2 Bruker Magnet Supervision Unit (BMU)

During normal operation, the magnet is supervised permanently by the Bruker Magnet Supervising Unit (BMU) . The magnet status can be checked in regular intervals using the supervising unit. The following BMU versions are available according to the different *magnet types [▷ 49]*:

MR instrument	Description
PharmaScan	US magnets (i.e. 70/16): BMU 4.2
BioSpec	USR magnets (i.e. 94/20): BMU 4.0
BioSpec	US/R magnets (i.e. 152/11): BMU 4.1

The BMU is located either in the dual-loop heat exchanger cabinet or in the high-power cabinet. Let an authorized person and/or the system owner show you the BMU functionality, and familiarize yourself with the magnet emergency button.

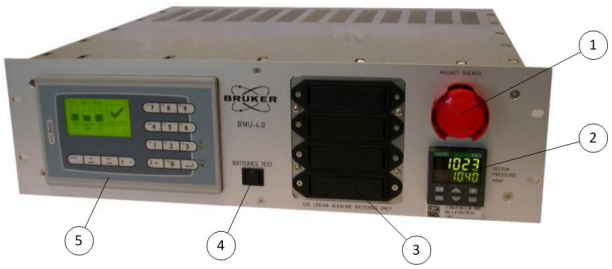


Figure 7.2: Bruker Magnet Supervising Unit (BMU)

Pos. No	Description
1	Magnet emergency quench button
2	Pressure controller (for USR magnets only)
3	Batteries
4	Batteries test button
5	Display and keyboard

7.2.2.1 Display and Keyboard

The status parameter and alarm messages of the magnet are displayed on the BMU front display. For US magnets, the nitrogen filling level is displayed continuously in the main menu.

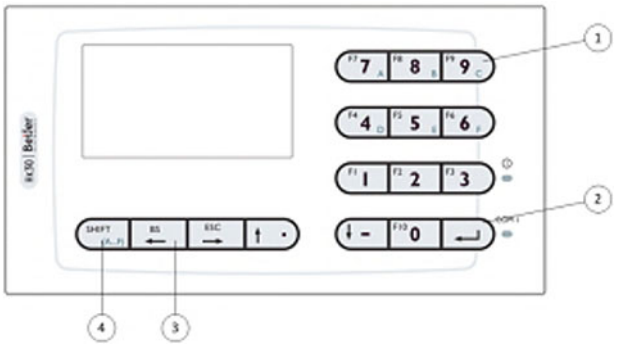


Figure 7.3: Display and Keyboard

Pos. No	Description
1	Numerical or function keys
2	Return key
3	Navigation key
4	Shift key

Using the shift key, you can access the Function Keys in the user menus. Therefore, press the shift key combined with the Numerical Key, e. g. Shift Key + Numerical Key 1 = F1 (Help Menu). The assignment of the Function Keys is listed in the following table.

Function key	Description
F1	Help Menu
F2	Alarm/Clear alarm
F3	Stop Buzzer
F4	Helium level/Start measurement
F5	Software and hardware version info
F6	Screening/Start screening
F7	Return to main menu
F8	Time and date setting
F9	Batteries/Test batteries
F10	Temperature

7.2.3 Magnet Emergency Quench Button

It is not required, that the user interacts with the magnet during normal operation conditions.

In the emergency case, the magnet can be quenched at any time using one of the emergency quench buttons (1) or (2). See section Safety, *Magnet Emergency Quench Button [▷ 21]* and familiarize yourself with the location and usage.

Figure 7.4: Magnet emergency quench buttons (1) and (2).

Magnets

8 Component Cabinet at the Magnet (CCM)

8.1 Overview

The component cabinet (CCM) is located at the service end of the magnet. The RF coil interface and, in some instrument configurations, also the quick-lock connectors for the gradient exchanging as well as the shim insert are stored in the CCM. In the following figure, the CCM is shown schematically.

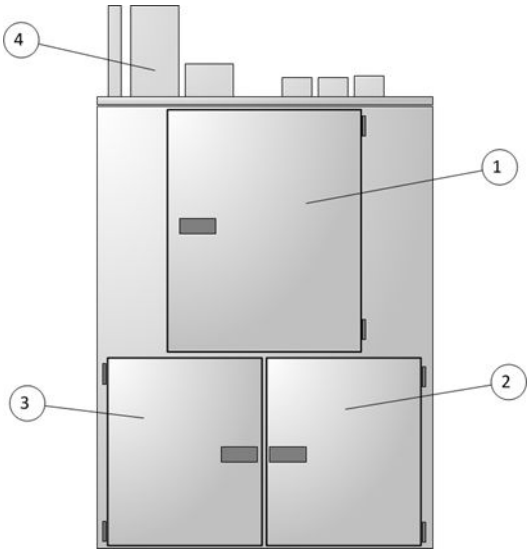


Figure 8.1: Component Cabinet at the Magnet (CCM)

Pos. No	Description
1	**Central upper door**: The central part of the CCM hosts the RF coil sockets to connect RF coils
2	**Lower right door**: The lower right part of the CCM hosts preamplifier, active detuning unit and the automatic hardware recognition units
3	**Lower left door**: The lower left part of the CCM provides all connections points to allow the exchange of gradient and/or shims inserts
4	**CCM filter panel**: Filter and feed through for the external cable set

The correct function of RF coil configuration depends critical on the wiring between sockets, active detuning module, preamplifier and receiver routing as well as the corresponding interface socket description of ParaVision.

NOTICE

The radio frequency coils are fragile and can easily be damaged irreversible. All components in the CCM (e. g. wiring, preamplifier) need to be precisely aligned to each other to ensure a proper functioning of the RF coils and components.

Do not modify neither the configuration settings, nor the DC or RF wiring.

8.2 RF Shielding

The MR instrument must be shielded against external interfering influences from the surrounding, to avoid image artifacts by interference with external RF signals. The shielding also protects external devices against the RF fields emitted by the MR instrument.

Depending on the magnet type and the site, the following RF shielding possibilities are available:

- Installation in a RF shielded cabin, often called Faraday cage. The Faraday cage includes an appropriate filter plate for the external cable set as well as an appropriate filter plate for animal supervision.
- Installation with RF screened CCM and AUTOPAC (MANPAC). The CCM is equipped with an appropriate filter plate for the external cable set. The AUTOPAC (MANPAC) provides appropriate filter plates for animal supervision.

While scanning, all doors of the CCM respectively the Faraday cage need to be closed. Scanning with open doors can cause image artifacts, and can negative affect EMC operating conditions in the environment possibly.

NOTICE

Surrounding RF interferences could reduce the image quality and/or cause image artifacts.

- ▶ Do not pass unfiltered conducting cables through the filter plate, the AUTOPAC, MANPAC or the CCM.
- ▶ Close all doors of the CCM respectively the Faraday Cage during a scan process.

9 Gradient and Shim Coils

MR instruments are equipped with at least one combined gradient and shim coil, which is permanently installed inside the bore of the magnet (called the system gradient and shim set). Depending on the configuration of the MR instrument, additional gradient inserts are available:

9.1 Reference Coordinate Systems

9.1.1 Physical Coordinate System

The physical coordinate system of the MR instrument is defined by the right-handed Cartesian coordinate system as shown in the figure below. This coordinate system is sometimes also called the “magnet coordinate system”. The origin of the physical coordinate system is defined by the magnetic center of the gradient coil. The magnetic center of the gradient coil is aligned with the magnetic center of the magnet[1)]. The magnetic field vector of the magnet is oriented towards the user end and is collinear with the positive field vector of the Z gradient coil[2)]. The shim coordinate system is always defined by the physical coordinate system of the gradient.

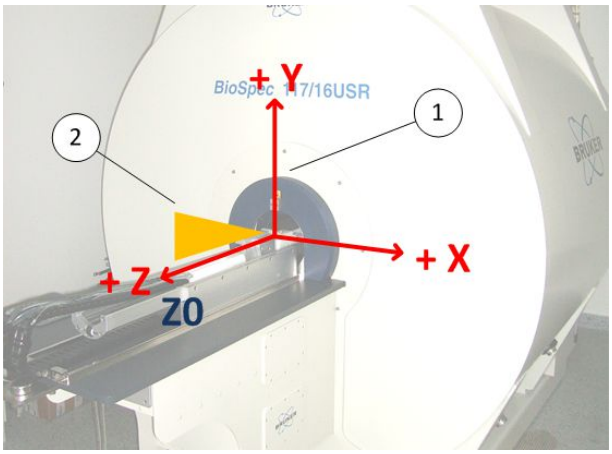


Figure 9.1: Right-handed Cartesian coordinate system

Pos. No	Description
1	Definition of the right-handed coordinate system of the MR instrument.
2	A positive current in one gradient channel increases the Lamor frequency of a spin along the corresponding positive axis. The example shows a positive current in the Z gradient coil, and correspondingly, the increase of the Lamor frequency towards the user end of the magnet.

1) Information about distances can be found on the type plate of the gradient and on the type plate of the magnet and are only required when a gradient set is mounted into the magnet. For the magnet, the reference point is the edge of the blue end ring at the service end of the magnet.

2) This is the standard polarization of all Bruker magnets. These magnets have their magnetic south pole at the user end and are sometimes referred to “SN” magnets. The polarization of the magnet is a critical parameter for the imaging coordinate system and for circular polarized RF coils. Suitable circular polarized RF coils are often referred as “QSN” coils.

9.1.2 Imaging Coordinate System

The imaging coordinate system is defined solely by the type of object/specimen under investigation. It serves as a normalized reference frame, sometimes also called the »Patient Coordinate System«. Many important parameters refer to the this imaging coordinate system, i.e. scan planning information, slice positioning, slice orientation, image labels, slice offsets and DICOM metadata. The origin of the imaging reference frame is always aligned with the origin of the physical coordinate system of the MR instrument.

ParaVision supports four different objects or specimen:

- **Materials:** For an intuitive representation, the imaging reference coordinate system of materials corresponds has been arbitrarily selected to correspond to the head supine human position. This is especially useful for microscopy applications of material in vertical MR instruments. Image labels are given in the right-handed Cartesian coordinate system as shown in (1) below.

- **Rodents:** The imaging reference coordinate system is defined by standard animal nomenclature and the DICOM anatomical orientation type “QUADRUPED”. Independent of the animal position inside the magnet, image labels are given in the right-handed Cartesian coordinate system as shown in (2) below.

- **Primates:** The imaging reference coordinate system is defined by standard primate (human) nomenclature and the DICOM anatomical orientation type “BIPED”. Independent of the primate position inside the magnet, image labels are given in the right-handed Cartesian coordinate system as shown in (3) below.

- **Others:** This imaging reference coordinate system is identical to the coordinate system of primates, see above. It can be used if the object under investigation does not belong to any of the predefined specimen.

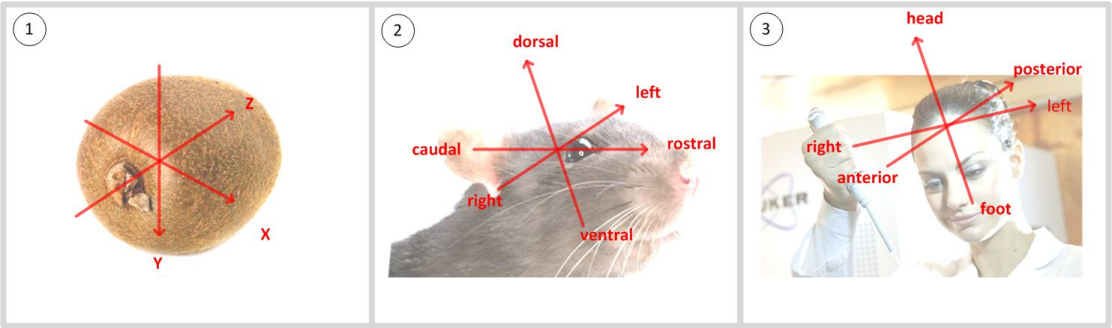


Figure 9.2: Imaging reference coordinate system

Pos. No	Description
1	Imaging reference coordinate system for **Materials**
2	Imaging reference coordinate system for **Rodents**
3	Imaging reference coordinate system for **Primates and Others**

For rodents, primates and others, the correct transformation between imaging coordinate system and the physical coordinate system of the MR instrument is automatically done by ParaVision and depends on the relative position of the object with respect to the MR instrument. The relative position of the object with respect to the scanner is defined during the study registration and cannot be changed within one study, i.e. head first / prone for a rodent that enters with the head first and which is in the natural prone position.

If the relative position of an object with respect to the scanner is incorrectly assigned during the registration of a study, all images and DICOM data sets of this study are incorrectly labeled. The scan planning, image analysis and interpretation do not supply usable scientific results.

Always pay attention to right object/sample position when register a study.

9.2 Acoustic Noise

Fast switching of gradient fields induce Lorenz forces inside the gradient coil, and as a consequence, acoustic noise is generated. Depending on the gradient switching scheme and the acoustic isolation between magnet room and console, wearing eartips can prevent damages due to acoustic emission.

9.3 Shimming

The magnetic properties of the sample can change between different regions of the sample, i.e. between air cavities and tissue. These changes of magnetic properties are responsible for local changes of the magnetic field strength, so called susceptibility field effects. Some imaging applications and most spectroscopy applications require very homogeneous magnetic fields across the region of interest. The susceptibility induced field changes between different regions of the sample can be (partially) compensated by the shim coils. This homogenization of the magnetic field is often called “shimming the sample”. For every new study, an automatic shimming process is started as a self-adjustment of the scanner.

9.4 Gradients

9.4.1 Overview

Gradient inserts can be used for experimental conditions where very strong gradient and shim fields are required over smaller sample regions. In this way, the gradient and shim performance can be ideally adjusted to the size of the sample. In the following table the different system gradients inclusive corresponding inserts are listed:

System Gradient	Gradient Insert 1	Gradient Insert 2
40 cm magnets: BGA 26 (HP)	BGA 12S HP	BGA 6S HP
30 cm magnets: BGA 20S HP	BGA 12S HP	BGA 6S HP
20 cm magnets: BGA 12S HP	BGA 6S HP	none
16 cm magnets: BGA 9S HP	none	none
11 cm magnets: BGA 6S-100	none	none

The following figure shows the gradient and shim connectors within the component cabinet (CCM).

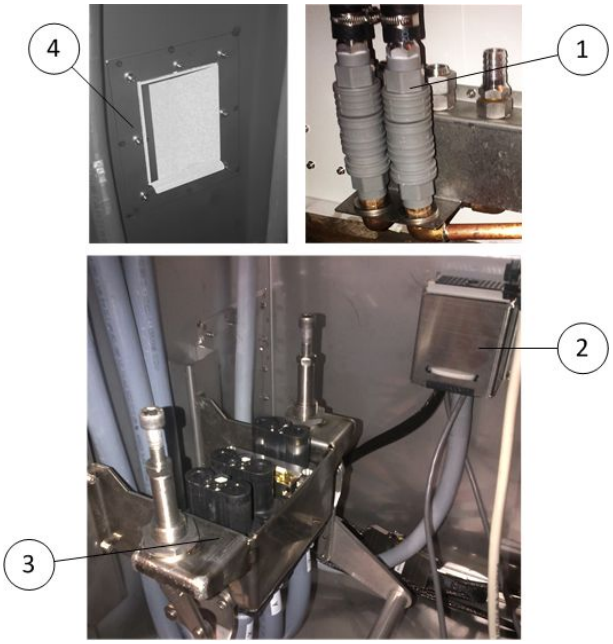


Figure 9.3: Gradient and shim coils within the CCM

Pos. No	Description
1	Outside wall of the CCM: Quick lock coupling for water cooling of the gradient insert
2	Lower left part of the CCM: Connector for shim sets (Hypertac)
3	Lower left part of the CCM: Connector for gradient sets (Schaltbau)
4	Central Left (or right) part of the CCM: RF shielded outlet channel for the water tubes of the insert

9.4.2 Duty Cycle and Water Cooling

During gradient switching, heat is dissipated inside the gradient coil. This heat is transferred into the water cooling system of the gradient coil. The gradient duty cycle is a measure about the quantity of thermal energy tolerated by the gradient and shim set.

The cooling system of the gradient coil is connected either to the heat exchanger or a stand-alone chiller, that is located in the technical room.

Cooling water needs to be checked from times to time and refilled by ordinary tab water if the filling level is too low. The gradient coil inner temperature as well as the filling level of the cooling system are supervised using appropriate sensors and interlock mechanism.

In order to avoid long-lasting gradient duty cycle violations, the current duty cycle is continuously monitored. The experiment is stopped as soon as the sensors detect a limit excess of the duty cycle.

ParaVision offers the possibility to calculate the duty cycle of an intended experiment before measurement begins.

Figure 9.4: Gradient-shim coil (example)

Pos. No	Description
1	Gradient and shim coil
2	Water tubes of the internal cooling system with quick-lock coupling

9.4.3 Exchanging Gradient Inserts

⚠ CAUTION

There is a risk of personal injury and/or property damage when lifting, carrying or installing the gradient insert.

Due to its weight (≥ 20 kg) the gradient insert has to be handled by at least 2 persons to avoid personal injury or damages.

- ▶ Ensure compliance with worker protection regulatory limits.
- ▶ Potentially, hire professional staff trained in handling heavy loads.

In order to install a gradient insert in the MR instrument, proceed as follows:

1. Switch the MR instrument in the operation mode System OFF.
2. Remove all RF coils and animal beds from the system gradient.
3. Move the insert from the service end of the magnet to the iso-center of magnet.
   - ➨ Information about the distances are labeled on the type plates of the magnet and gradient insert.
4. Adjust the rotation of the gradient insert in such a manner, that the thick mark is oriented along the physical +Y axis of the magnet coordinate system (12 o'clock position). Refer to section *Physical Coordinate System [▶ 57]*.
5. Fix the gradient insert with the non-magnetic tools. Therefore, carefully turn the eccentric screws until the gradient insert is well fixed. Do not apply brute force!
   - ➨ The tool is in the scope of delivery.
6. Disconnect the gradient current connector (Schaltbau) of the system gradient set inside the CCM and connect the equivalent connector of the new insert.
7. Disconnect the shim current connector (Hypertac) of the main shim set inside the CCM and connect the equivalent connector of the insert.
8. Feed the water cooling tubes of the insert through the RF shield on the side of the CCM.
9. Remove the U-shaped bypass tube and connect the cooling tube of the gradient insert at the water distribution panel

10. Switch the MR instrument in the operation mode *System ON [▷ 35]*.

NOTICE

Each kind of mechanical force can cause property damage to the gradient shim system and its connectors.

- ▶ Avoid each kind of mechanical force such as bumps or shakes when connecting the gradients and shims.
- ▶ Do not twist any housing, sealing or quick-lock connectors.
- ▶ Always use the protective cover of the shim connector, when the insert or the main shim set is not connected.

10 Preparation Tables and Animal Cradles

The MR instrument can be equipped with different types of preparation tables. All preparation tables include different sliding systems, on which different animal cradles can be mounted. The animal cradles are available with or without integrated RF coils.

- **Manual Sliding System:** This preparation table is an adjustable three-axis table including sliding rails. This table is available as model “Bracket” for 11, 16 and 20 cm magnets or as model “Slider” for 30 and 40 cm magnets. Distance measurements are done using simple tools like non-magnetic rulers and ticks.

- **AUTOPAC:** This motorized animal positioning system corresponds to a clinical patient bed for rodents. The AUTOPAC is controlled and positioned precisely using a laser crosshair and a digital control panel. Furthermore, the system provides an RF shielded cover as well as an anesthesia and animal supervision filter plate, when MR instruments are installed without Faraday cage.

- **MANPAC:** This manual animal positioning system corresponds to a manual operated AUTOPAC. Using a mechanical distance definition system positions can be realized precisely and reproducibly. Furthermore, the system provides an RF shielded cover as well as an anesthesia and animal supervision filter plate, when MR instruments are installed without Faraday cage.

Figure 10.1: AUTOPAC and MANPAC System

Pos. No	Description
1	AUTOPAC and MANPAC designed with identical cover
2	Manual Sliding System with slider rail of the *Bracket* model

The animal cradles are available for mice, rats, guinea pigs and small rabbits. Beds for mice and rat are designed in a modular way to support different specialized applications. They consist of a basic bed and exchangeable so called TIPs. TIPs are designed for the usage with the corresponding dedicated RF coils.

These beds are suited for animals with a body weight up to 400 – 500 g. The AUTOPAC may be loaded with maximum 5 kg.

In order to ensure the best possible image quality, the combinations of animal cradles and RF coils listed in the following sections should be used for in vivo applications.

10.1 Animal Cradles and RF Coils for Mouse in vivo Applications

Application	RF Coil	Corresponding Animal Cradle
Brain	Mouse Brain Surface Receive Coils	Base Mouse Cradle with SUC TIP
	Mouse Brain Array Coil (4CH)	Base Mouse Cradle with SUC TIP
	Mouse Brain Array Coil (8CH)	Coil is integrated in the cradle
	Mouse CryoProbe	CrypProbe Mouse Cradle
Head	23 mm Volume Coil	Base Mouse Cradle
	Mouse Brain Array Coil (8CH)	Coil is integrated in the cradle
	Mouse CryoProbe	CrypProbe Mouse Cradle
Body	40 mm Volume Coil	Base Mouse Cradle with BODY TIP
	35 mm Volume Coil	35 mm Mouse Cradle
	Mouse Body Array Coil (8CH)	Coil is integrated in the cradle
	Mouse CryoProbe	CrypProbe Mouse Cradle
	10 – 30 mm Surface Receive Coils	Base Mouse Cradle with SUC TIP
Heart	40 mm Volume Coil	Base Mouse Cradle with BODY TIP
	Mouse Cardiac Array Coil (4CH)	Base Mouse Cradle
	Mouse Brain Array Coil (8CH)	Coil is integrated in the cradle
	Mouse CryoProbe	CrypProbe Mouse Cradle
Subcutaneous	10 – 30 mm Surface Receive Coils	Base Mouse Cradle with SUC TIP
	Mouse CryoProbe	CrypProbe Mouse Cradle

10.2 Animal Cradles and RF Coils for Rat in vivo Applications

Application	RF Coil	Corresponding Animal Cradle
Brain	Rat Brain Surface Receive Coils	Base Rat Cradle with SUC TIP
	Rat Brain Array Coil (4CH)	Base Rat Cradle with SUC TIP
	Rat Brain Array Coil (8CH)	Coil is integrated in the cradle
	Rat CryoProbe	CrypProbe Rat Cradle
Head	40 mm Volume Coil	Base Rat Cradle
	Rat Brain Array Coil (8CH)	Coil is integrated in the cradle
	Rat CryoProbe	CrypProbe Rat Cradle
Body	60, 72 or 86 mm Volume Coil	60 mm Rat Body Cradle, Base Rat Cradle with SUC TIP (72, 86 mm)
	Rat Body Array Coil (8CH)	Coil is integrated in the cradle
	Rat Body Array Coil (16CH)	60 mm Rat Body Cradle
	30 mm Surface Receive Coils	Base Rat Cradle with SUC TIP
Heart	60, 72 or 86 mm Volume Coil	60 mm Rat Body Cradle, Base Rat Cradle with SUC TIP (72, 86 mm)
	Rat Cardiac Array Coil (4CH)	Coil is integrated in the cradle
	Rat Body Array Coil (8CH)	Coil is integrated in the cradle
	20 and 30 mm Surface Receive Coils	Base Rat Cradle with SUC TIP
Subcutaneous	10 – 30 mm Surface Receive Coils	Base Rat Cradle with SUC TIP
	Rat CryoProbe	CrypProbe Rat Cradle

10.3 Animal Cradles and RF Coils for Large Rodents and Materials

Application	RF Coil	Corresponding Animal Cradle
Diverse	15 mm Volume Coil	none
	25 mm Volume Coil	none
	35 mm Volume Coil	35 mm Mouse Cradle
	60 mm Volume Coil	60 mm Rat Cradle
	72, 86 mm Volume Coil	Base Rat Cradle with SUC TIP
	154 mm Volume Coil	Guinea Pig Cradle
	198 mm Volume Coil	Rabbit Cradle

10.4 Using Animal Cradles

All Bruker animal cradles are compatible with the different animal positioning systems. This is possible via a standardized interface connection point common to all positioning systems.

Figure 10.2: Animal cradles – overview

Pos. No	Description
1	Animal cradles
2	Sliding system
3	Placing hook
4	Fixing screw

The following figure shows two different configurations of the mouse base bed. The mouse head TIP illustrated on the left is used together with the 23 mm volume coil and the mouse base bed, which form the configuration for mouse head investigations. The mouse brain TIP (TIP RFSUC) illustrated on the right is used together with brain surface coils or surface coil arrays for mouse brain investigations.

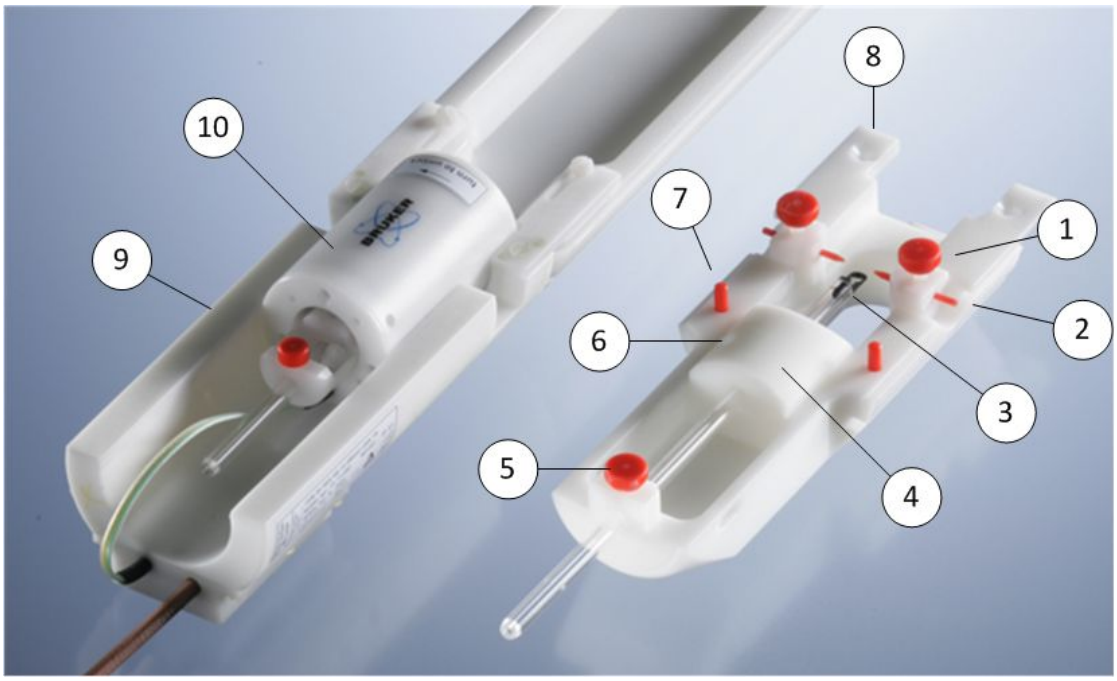


Figure 10.3: Mouse base bed configurations

Pos. No	Description
1	Ear plug screws
2	Animal ear plugs (optional)
3	Animal tooth bar with bite bar
4	Anesthesia block
5	Fixing screw for anesthesia block
6	Fixing screw
7	Retaining coil pin
8	TIP fixing screws
9	Mouse head tip
10	23 mm volume coil

Die animal cradles provide various functions:

- **Size adjustment:** Different sized animals can be placed safely using the mouth cone and anesthesia block (4). Therefore, loosen the fixing screws (6) and (5), and move the block in the required position.
- **Fixation:** The animal head is fixed using the tooth bar and optional ear plugs. Therefore, hook the front teeth of the mouse into the bite bar (3). Place the mouse on the bed and pull the bite bar back until the mouse is properly positioned in the anesthesia block.
  If required, the ear plugs can be used to fix the mouse head stereotactically. Therefore, loosen the ear plug screws (1) and slip the ear plugs (2) gently into the mouse ears. Fix the ear plug using the screws.
- **Anesthesia:** The anesthesia gases can be adminster via the nose using the nose cone of the TIP. Therefore, connect the gas tube to the anesthesia block via the Luer coupling. Place the tube in a wide loop and fix it in the side channels of the base bed. Make sure, that the tube cannot be squeezed when inserting the bed into the magnet. The anesthesia gases is extracted either passive via a stand-alone extraction or actively via the nose cone extraction channels respectively the tooth bar.
- **Body temperature stabilization:** The animal's body temperature can be stabilized using the integrated water-based warming meander. Therefore, connect the black quick-lock coupling to the external warming circuit.
  Different sized flexible water based warming pads are available for animal cradles, which are not equipped with integrated warming circuits.
- Use the TIP fixation screws (8) to exchange the mouse head TIP and coil against the TIP RFSUC.

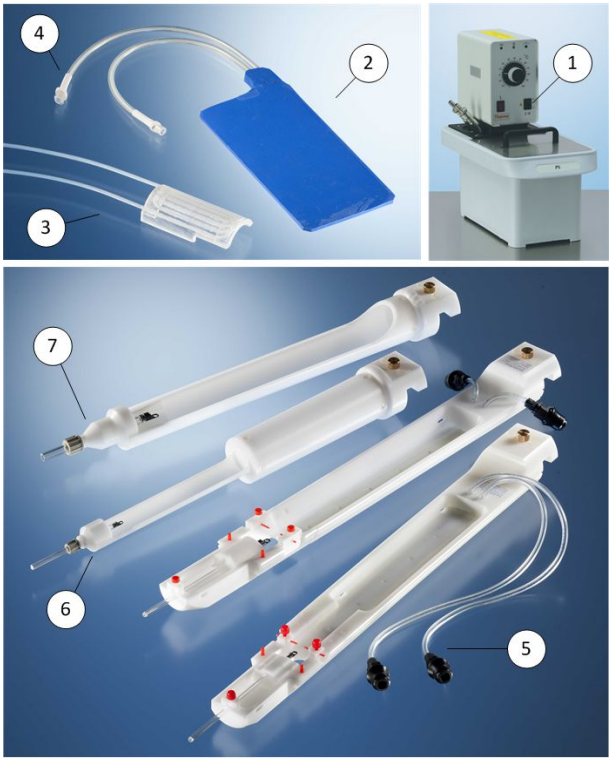


Figure 10.4: Mouse bed components in detail

Pos. No	Description
1	Animal temperature stabilization unit
2	Flexible warming pad

Pos. No	Description
3	Warming pad for the mouse body bed
4	Luer coupling for warm water circulation, used in combination with the bypass (not shown)
5	Quick lock coupling for warm water circulation
6	Mouse bed 30
7	Rat bed 60

10.5 Using AUTOPAC

The AUTOPAC is an automatic animal positioning system. In combination with different animal beds, it is used to position the animal as desired within the magnet. The AUTOPAC is operated using the control panel on the preparation table:

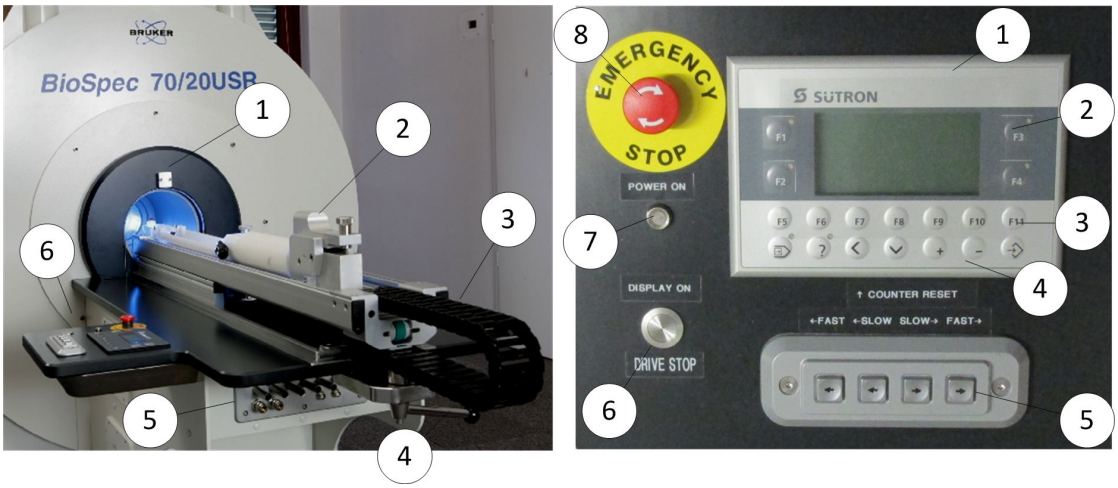


Figure 10.5: AUTOPAC (on the left) with control panel (on the right)

Pos. No	Description	Pos. No	Description
1	Laser cross hair	1	Control panel and display
2	Bed interface and height adjustment	2	Main Function keys F1 – F4
3	Drag chain	3	Additional Function keys F5 – F11
4	RF cover lock	4	Configuration and Service keys
5	Anesthesia filter plate	5	Manual drive buttons (slow, fast)
6	Control panel	6	Display ON / Drive Stop
		7	Power On control LED
		8	Emergency Stop

Function keys:

F1	**START POSITION**	Initial step to drive the bed to the zero position (completely out)
F2	**LASER ON/OFF**	Schwitch the laser cross hair ON/OFF
F3	**WORK POSITION**	Drive the bed to the work position in the center of the magnet
F4	**LASER POSITION**	Drive the bed back to the last selected laser position
F5 – F11		Not used.

Manual drive buttons:

<	**IN FAST**	Fast manual drive in the bore.
<	**IN SLOW**	Slow manual drive in the bore.
>	**OUT SLOW**	Fast manual drive out of the bore.
>	**OUT FAST**	Slow manual drive out of the bore.

Configuration and Service keys have different meanings depending on the service mode. The most important ones for the user regarding possible trouble shooting are listed below. Please refer also to the technical documentation of the MR instrument.

	**Home**	Not used.
?	**Motor Force**	Change the collision protection level (0=low, 25=high).
<	**NULLING**	Set a temporal new reference position.
v	**DISTANCE**	Set the distance between laser and magnet center.
+	**PLUS**	Increase a value.
–	**MINUS**	Decrease a value.
□	**RETURN**	Acknowledge and return to main menu.

The AUTOPAC provides the following functionality:

- **Height adjustment:** The height of animal beds is set using the screw (2). Turning the screw clockwise to move the bed upwards. Carefully adjust the height of the bed to avoid that the animal and/or the receive coils touch the volume coil in the magnet.
- **Positioning of the animal** in the center of the magnet is done by the following steps:

▶ Prerequisite: Zero position has been initialized with F1.

1. Turn the Laser on by pressing the function key F2.
2. Move the animal under the laser cross hair in the desired position using the manual drive buttons (inner buttons: slow movement, outer buttons: fast movement).
3. Turn the laser off by pressing function key F2.
4. Press F3 to move the animal automatically into the magnet center.
5. Observe carefully to move the animal in a safe manner.
6. Remove the animal out of the magnet using the function keys F1 or F4.

Stop and Resume

Press the “Drive Stop” button to interrupt the sample movement, for example to readjust the sample’s height. Press F3 to resume the movement.

- **Setting a Reference position.** In some cases it might be useful to set a certain animal position as a temporal reference position, i.e. in order to make small position changes based on this position. This is facilitated by setting the actual position counter to zero. After nulling the position, the relative distance (label **R**) is displayed with respect to the new reference position. The actual position remains unchanged (label **A**).

- **RF screening** is achieved by placing the AUTOPAC cover (1) and by locking it with the handle (2). The display turns off as soon as the cover is locked.
  Press the DISPLAY ON button to switch the display on, refer to position no. (6) in the figure shown before.

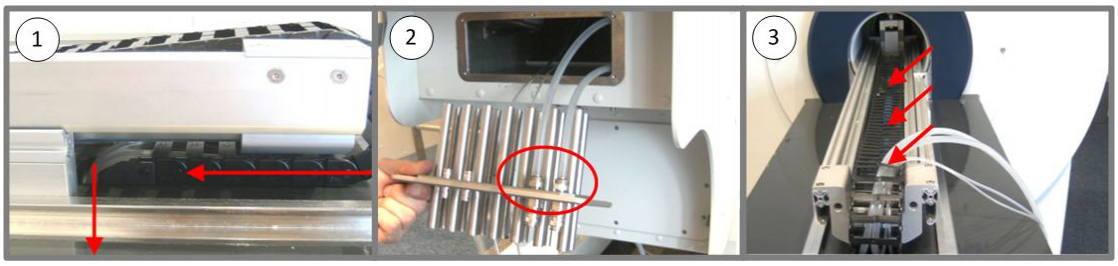
Figure 10.6: AUTOPAC RF screening

Pos. No	Description
1	AUTOPAC cover
2	Handle

- **Collision protection:** In order to protect the operator and the animal from being injured or hardware from being damaged, a safety measure – a so-call collision protection – is performed. If a collision is detected, the drive motor stops immediately. Before you reset the protection, always make sure that the reason for triggering the collision protection is solved. Press the »Emergency Stop« button to clear the error state, refer to position no. (8) in the figure shown before. You can change the threshold of the collision protection using the »Motor Force« Service key between 0 (low threshold) and 25 (high threshold). After a collision protection stop has occurred, the actual position of the sled might be undefined. Press F1 to drive the sled completely out to initialize the position.

- **RF filtered feed through: The cables for** animal supervision and the anesthesia gas tubes must always be lead through the AUTOPAC filter plate. For the installation of new signal lines, proceed as follows:

1. Drive the empty sled all way into the magnet.
2. Remove the filter plate with a non-magnetic Allen key (size 4).
3. Push all cables, tubes, fiber optics into the crawler (1) and grab them from the opening of the filter plate. Pull all cables through the front opening of the filter plate (2).
4. Use the appropriate feed-through and filter of the filter plate to connect tubes, cables, etc.
5. Mount the filter plate.
6. Place all cables, tubes, fiber optic cables carefully in the crawler (3). Close the crawler.



⚠ CAUTION

The RF screen springs are pointed or sharp-edged. You can injure yourself easily.

- ▶ Avoid to damage, bend and/or lose the RF screen springs.
- ▶ Handle the RF screen spring with care and return them to its original position.

10.6 Using MANPAC

The MANPAC is a manual animal positioning system. In combination with different animal beds, it is used to position the animal as desired within the magnet. MANPAC is operated manually.

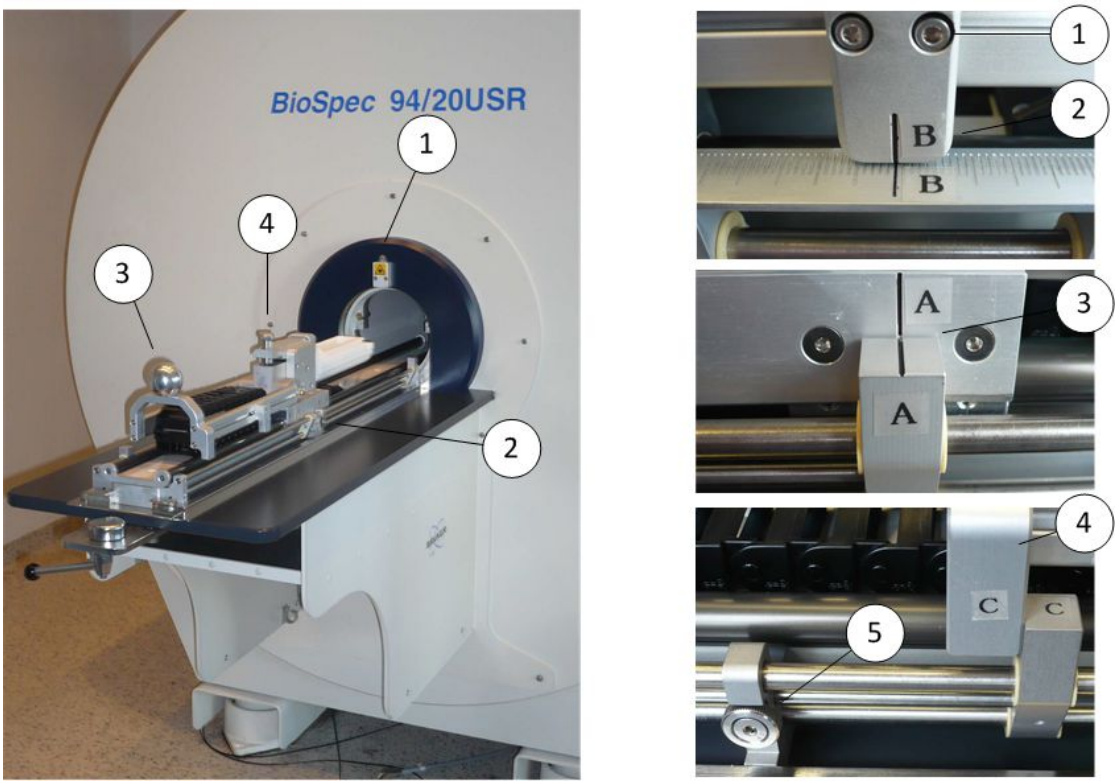


Figure 10.7: MANPAC (on the left) with sliding system (on the right)

Pos. No	Description	Pos. No	Description
1	Laser cross hair	1	CENTER Position screws
2	FIX Position block (right side)	2	CENTER Position marker
3	Handle to move the animal bed	3	ROI marker
4	Height adjustment	4	FIX position block
		5	Adjustment screw

The MANPAC provides the following functionality:

- **Height adjustment:** The height of the animal beds is set using the screw (4). Turning the screw clockwise to move the bed upwards. Carefully adjust the height of the bed to avoid that the animal and/or the receive coils touch the volume coil in the magnet.
- **Positioning of the animal** in the center of the magnet is done by the following steps:

1. Activate the Laser by pressing the button on top of the laser.
   ➨ The light will remain on for approx. 20 s.
2. Move the animal under the cross hair until the crosshair indicates the desired region of interest.

3. Open the adjustment screw (5) on the right side and move the marker A (3) until it co-aligns with its partner mark. Close the adjustment screw gently.
4. Move the animal bed inside the magnet until the mark B co-aligns with the partner mark. The region of interest is now in the center of the magnet. Pay attention that the animal bed doesn't touch or block while it is moved inside the magnet.

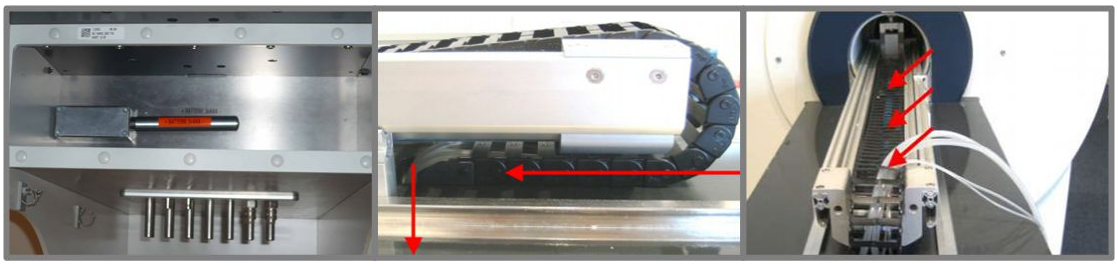
- **FIX position:** Sometimes, it is desired to take the sample out and bring it back into exactly the same position. This can be achieved using the FIX position block C (4). Losen the adjustment screw (5) and move it against the FIX block counterpart. Close the adjustment screw (5) again. The next time the sample is inserted into the magnet, it will always come back to the identical position. Please notice, release the fix block position, when it is no longer required.
- **RF screening** is achieved by placing the MANPAC cover (1) and by locking it with the handle (2).

Figure 10.8: MANPAC HF-Screening

Pos. No	Description
1	MANPAC-Abdeckung
2	Handle

- **RF filtered feed through** of animal supervision and anesthesia gases must always be lead through the MANPAC filter plate. For the installation of new signal lines, proceed as follows:

1. Drive the empty sled all way into the magnet.
2. Remove the filter plate with an non-magnetic Allen key (size 4).
3. Push all cables, tubes, fiber optics into the crawler and grab them from the opening of the filter plate. Pull all cables through the opening of the filter plate (2).
4. Use the appropriate feed-through and filter of the filter plate to connect tubes, cables, etc.
5. Mount the filter plate.
6. Place all cables, tubes, fiber optic cables carefully in the crawler (3). Close the crawler.



- **Calibration of the CENTER Position:** The CENTER position is calibrated before installation. Proceed as follows:

1. Place a small MRI sample under the laser cross hair and align the A marker.
2. Move the sample into the magnet and verify the central positioning for instance by a suitable imaging experiment. Move the animal bed such that the sample is precisely in the center of the magnet.
3. Losen the two center position screws (1) and move the reference block such that the two B marks co-align. Close the two center adjustment screws.

⇨ The MANPAC is now correctly calibrated.

The batteries of the laser are located under the table of the MANPAC, close to the filter plate. To exchange them, unscrew the battery housing and replace them with 3 batteries of type AAA.

⚠ CAUTION

Batteries can be magnetic. There is thus a risk, that you can injury yourself and/or damage the magnet.

- ▶ Before exchanging, keep the batteries in the housing and carry them out of the controlled access area.
- ▶ Be particularly circumspect when you mount the batteries again.

⚠ CAUTION

The RF screen springs are pointed or sharp-edged. You can injure yourself easily.

- ▶ Avoid to damage, bend and/or lose the RF screen springs.
- ▶ Handle the RF screen spring with care and return them to its original position.

10.7 Using the Manual Slider Systems

There are two different variations of the manual slider system variations. A bracket version for small magnets suited for mice and rats (left image) and a slider system for 30 and 40 cm magnets that can also handle bigger rodents of up to 5 kg (right image).

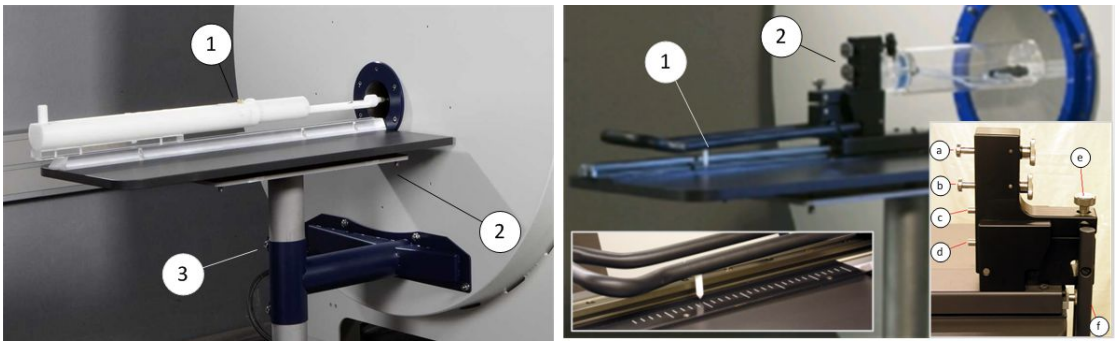


Figure 10.9: Manual Slider Systems

Pos. No	Description	Pos. No	Description
1	Interface and secure screw	1, f	Handle for slider with ruler
2	Fine adjustment screws	2	Interface and holding bolts (see inlet)
3	Height adjustment	a, b	Hooks & screws to fix the animal bed
		c, d	Bolts to align animal beds
		e	Height adjustment

The position of the preparation table is adjusted during the installation by the Bruker Service. The table position can be varied using a non-magnetic Allen key. The Allen key is included with delivery of the preparation table and is normally stored at the table's base. The table's height is adjusted coarsely and aligned using the clamping screws at the stand of the table.

Tips

Injury of animals

Never apply strong forces to overcome resistances when sliding the sample into the magnet. The animal could be injured.

- Always ensure free access and check the correct alignment of the animal bed in the magnet bore.

Functions of the Bracket System

On the bracket system, the animal beds are simply inserted from one end into the bracket. For smooth sliding of the bed, the bracket can be moistened with small amount of a silicon based lubricant.

- **Positioning:** Sample and animal bed are simply inserted from one end into the bracket. For smooth sliding of the bed, the bracket can be moistened with small amount of a silicon based lubricant. A non-magnetic ruler, which is provided with the MR instrument, can be used to measure the exact position of the sample in the magnet. Often, users mark important positions on the bracket.
- **Height and tilt adjustment:** The height and tilt of the preparation table are performed using the four Allen screws, located on the table's bottom side.

Functions of the Slider System

On the slider system, the animal beds are hooked into the hooks and bolts. The bed is fixed by gently closing the screws at the opposite side of the hook.

- **Positioning:** Sample and animal bed are simply inserted from one end into the bracket. For smooth sliding of the bed, the bracket can be moistened with small amount of a silicon based lubricant. A non-magnetic ruler, which is provided with the MR instrument, can be used to measure the exact position of the sample in the magnet. Often, users mark important positions on the bracket.
- **Height and tilt adjustment:** The height and tilt of the preparation table are performed using the four Allen screws, located on the table's bottom side.

11 RF Coils

The correct choice of the RF coil configuration for a given in-vivo investigation has an important impact on the quality of the results. In general, an RF coil configuration can contain one or several individual RF coils that form all together the RF coil configuration, i.e. the usage of separate RF coils for signal excitation and signal detection.

One might distinguish between two main types of RF coil configurations:

- **Transceiver coil configuration:** signal excitation and signal detection are done with the same RF coil. The RF coil itself can be a volume or surface coil, single or double resonant. A synonym for transceiver coil is transmit/receive coil.
- **Cross coil configurations:** signal excitation is done with a different RF coil than signal detection. In most cases, the excitation coil is a dedicated volume coil whereas the signal detecting coil is a small coil located as close as possible to the region of interest. The excitation coil in these coil configurations is optimized for a homogeneous excitation profile and coupling between the excitation coil and the receive coil is minimized. In this configuration, the excitation coil (transmit coil) may be a transmit-only or a transmit/receive coil with Active Detuning (AD). In the cross coil mode, a transmit/receive coil servers as transmit coil in combination with the separate receive-only coil used for signal detection. However, via ParaVision, the mode can be switched so that for certain applications, the transmit/receive coil can also be used for signal detection (TxRx Volume Coil Mode). In this case, the receive-only coil is although present in the magnet but not used for image acquisition.

Please remark that also mixtures of these two basic types can exist, i.e. coil configurations for pulsed arterial spin labeling or double resonance experiments.

Please refer to Chapter *Animal Cradles and RF Coils for Mouse in vivo Applications [▶ 64]*, *Animal Cradles and RF Coils for Rat in vivo Applications [▶ 65]*, *Animal Cradles and RF Coils for Large Rodents and Materials [▶ 66]* for the selection of the best suited combination between RF coils and animal beds for various applications.

Due to the great number of different RF coil types and designs, Bruker offers an introduction of the terminology used in this manual, refer to section *RF Coil Terminology and Identification [▶ 79]*. If you are not yet familiar with the RF coil terminology, it is helpful to have a quick look at it. Parts of this (Bruker) terminology are also used on the type plates of the RF coil and can be used to identify the coil.

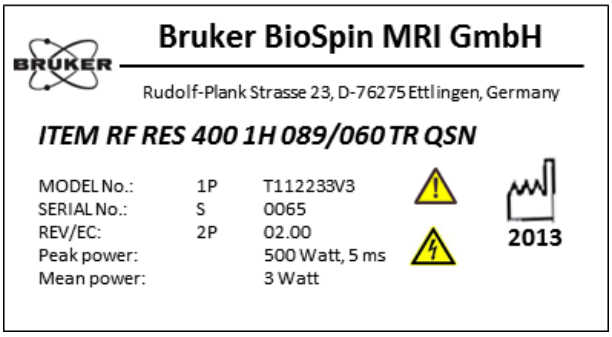
11.1 RF Coil Terminology and Identification

The type plate of the coil contains information about properties and power specifications of the coil.

Head Coil	examination of the head of an animal
Brain Coil	examination of the brain of an animal, but not the entire head
Body Coil	examination of parts of the body of an animal, but not the entire animal
Whole Body Coil	examination of the entire body of an animal (excluding the tail).
Volume Coil	a coil that covers a closed volume
Surface Coil	a coil that is normally open on one side and covers a half volume

Array Coil	A coil that has multiple coil elements and can be receive-only or a transceiver coil
1H/X Coil	a double resonant coil; both resonance frequencies can be used simultaneously.
1H-X Coil	a single resonant which can be tuned in the given range of nuclei
transceiver coil	the coil can be used for signal excitation and signal detection
receive-only coil	The coil can only receive signal, but cannot be used for signal excitation
RF coil configuration	The coil configuration describes the set of one or more RF coils that are used in a study. The name of the configuration is defined by the user.
RF Coil	a single coil that is used in a RF coil configuration
RF coil element	one of the RF channel(s) of a single or multiple element RF Coil or coil array.
RES	Resonator or Volume Coil.
SUC	Surface Coil, single or double resonant.
ARR	Array Coil.
CRP	MRI CryoProbe TM
AD	Active detuning, required property of all coils in a cross coil configuration
TR	Transceiver coil
TO	Transmit-only transmitter coils, cannot be used for signal detection.
RO	Receive-only coil, no signal excitation possible.
PC	PET Compatible. RF Coil can be used during PET applications. Typically for these RF Coils, attenuation correction maps are provided in ParaVision. Compare PO.
PO	PET Optimized. RF Coil focuses on PET application with regard to FOV, material (low attenuation) etc. Typically for these RF Coils, attenuation correction maps are provided in ParaVision.
QSN/QNS/QUAD	Circularly polarized RF Coil, polarity south-north / north-south / unspecific

The type plate of the coil contains information about properties and power specifications of the coil, for instance as shown in the example below:



RES: it is a resonator or Volume Coil

400: it is designed for 9.4T instruments (400 MHz)

1H: the coil is designed for 1H nucleus

089: the outer diameter is 89 mm

060: the inner diameter is 60 mm

TR: it is a transceiver coil without active detuning (no “AD” tag in the item)

QSN: circularly polarized (quadrature) coil for SN magnets

11.2 Installing RF Coils

For personal safety and material damage reason, please follow the instructions below when handling RF coils.

NOTICE

The RF coils and the sample can easily be damaged.

- ▶ Never install RF coils with damaged housing or damaged cables.
- ▶ Connect all RF coils of the configuration to be used before starting the Exam Card in ParaVision and scanning. For safe and appropriate use, the RF coils need to be recognized by the software.
- ▶ Handle RF coils with great care.
- ▶ Avoid each kind of mechanical influence (hits, bumps or shakes). They could damage the RF coil.
- ▶ Take great care to avoid liquids entering the coil housing.
- ▶ Do not overwind the tuning or matching rods.
- ▶ Ensure that the RF coil will not interfere mechanically with the sample when inserting in or removing out of the magnet. This may damage the sample or the RF coil.
- ▶ Be particularly circumspect when mounting RF coils on living animals.

NOTICE

Receive-only coils are likely to be damaged when not connected to the coil socket(s) or used with a wrong coil configuration.

- ▶ Ensure that coils inside the transmission coil are correctly connected to the socket.
- ▶ Ensure that the correct coil configuration is selected.

11.2.1 Magnet mounted Volume Coils

These RF Volume Coils are mounted directly inside the gradient bore and fixed by inflating the pneumatic fixation system.

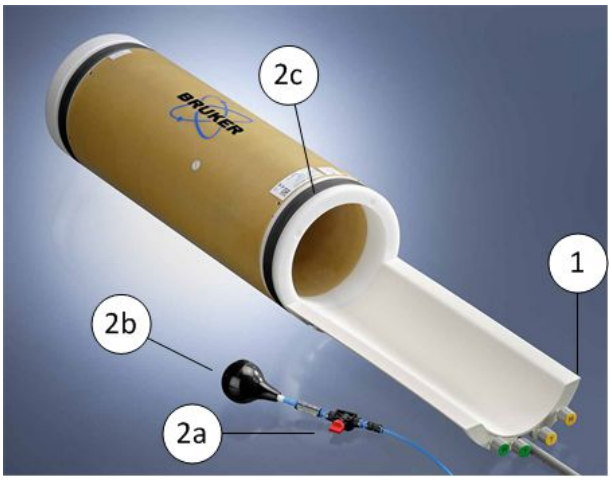


Figure 11.1: Magnet mounted RF coil – example

Pos. No	Description
1	Coil housing
2a	Valve
2b	Balloon
2c	Pneumatic rings

Mounting instructions:

1. Insert the coil from the service end and co-align the coil housing (1) with the end of the gradient tube.
2. Switch the valve (2a) in the “pump” position.
3. Gently pump and inflate the rings (2c) of the pneumatic fixation system using the balloon (2b).
4. Connect the coil with the corresponding RF interface socket according to the color labels.

To remove the coil from the magnet, proceed as follows:

1. Stop any running scan prior to disconnecting or dismounting a RF coil.
2. Unplug the coil using the leverage effect of the coil socket cover.
3. Open the valve of the pneumatic fixation system.
4. Remove the coil out from the gradient bore.

NOTICE

The components of the pneumatic fixation system can easily be damaged.

- ▶ Never pump and inflate the rings of the pneumatic fixation system outside a surrounding bore to avoid exceeded inflation and damage of the system.
- ▶ Do not apply high pressure to the components of the pneumatic fixation system. Gently pump by hand.

11.2.2 Animal Cradle mounted RF Coils

Receive-only RF coils of cross coil configurations or small volume coils for mice and rats are typically mounted on the animal cradle. First the animal is prepared on the cradle and then the RF coil is mounted onto the cradle (1) or shifted over the animal (2). Finally, the entire setup is moved into the magnet bore from the user end (front end) of the MR instrument.

Figure 11.2: Animal cradle with studs to mount the RF coil (1) and mouse head coil shifted over the animal cradle (2) – typical examples of various setups.

Pos. No	Description
1	Mouse bed, prepared for hosting surface brain coils and brain array coils
2	Mouse head volume coil

Mounting instructions:

1. Prepare the animal cradle for the desired application by attaching the correct TIP to the base cradle.
2. For surface coils and surface arrays coils: Insert the RF coil from the service end and push it through the magnet. Connect the coil at the corresponding RF coil socket. Goto the user end and place the coil in the magnet front bore or on the preparation table.
3. Prepare the animal and the animal supervision. Take the animal cradle with the animal into the magnet room and connect it to the animal cradle interface of the positioning system.
4. Place the RF coil on the cradle and fix it with some tape, if required.
5. Move the animal and the RF coil carefully into the iso-center of the gradient system.

11.2.3 MRI CryoProbes

Please refer to the corresponding CryoProbe (Cryo Coil) on the MRI RF Coil CD and follow all instructions given therein.

11.3 Connecting RF Coils

MRI RF coils are connected to the MR instrument at the sockets of the RF coil interface, located inside the CCM at the rear side of the magnet. The RF coil interface consists of up to 4 color-coded sockets, that are used for the following types of RF coils:

• grey, labeled »TR 1H«	Main 1H transceiver coils.
• Blue, labeled »TR BB«	Broadband X nucleus transceiver coils
• Orange, labeled »RX only (1)«	Receive-only coils, labeled »RX only« with up to 8 receive elements.
• Orange, labeled »RX only (2)«	Receive-only coils, labeled »RX only« with up to 8 receive elements. Together with RX only (1), a total of 16 receive elements are supported.

Each plug and socket contains multiple contacts to connect RF signals, automatic hardware recognition, detuning and control signals of the instrument with the RF coil.

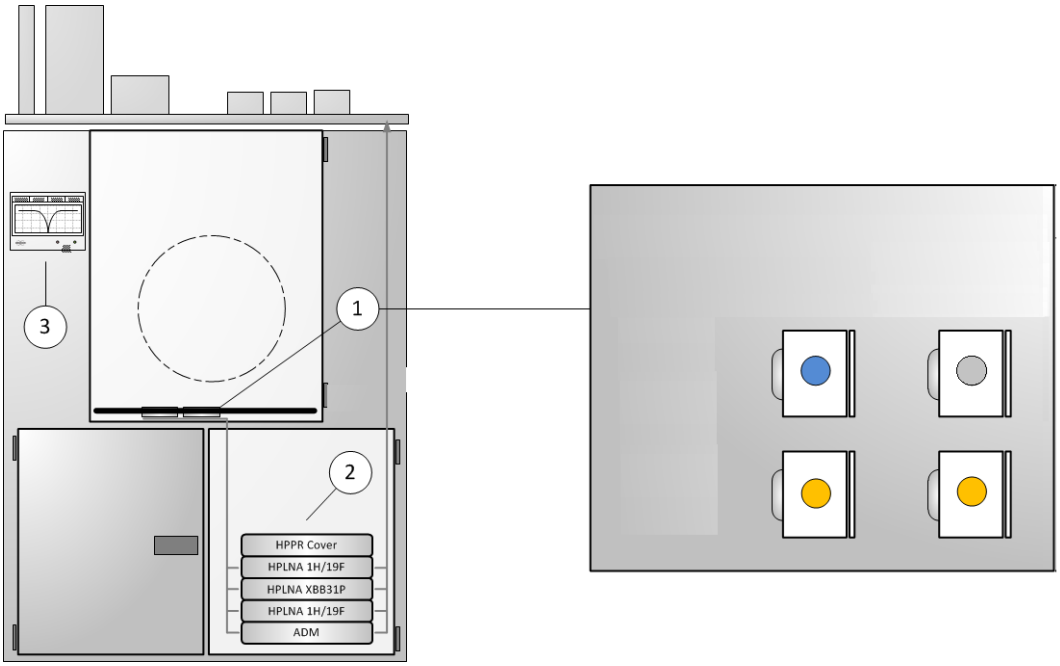


Figure 11.3: RF Coil Interface AVANCE NEO inside the CCM.

Pos. No.	Description
1	Socket interface of the MR instrument, located inside the CCM
2	Preamplifier stack, hardware recognition and active detuning devices of the coil interface
3	RF interface display (touch-screen)

11.4 RF Interface Display

The RF interface display is located at the outside or on top of the CCM. The display provides information on different tabs to be toggled via touch screen display.

For routine operation, only the »Wobble« tab is relevant for the user:

- **Wobble:** the wobble tab shows the module name and the corresponding tune/match (wobble) curve(s). The wobble process can be controlled by the following commands:
  - **STOP:** Stop the tune/match process.

- **PREV:** Go to the previous channel (quadrature and/or double resonant coils).
- **NEXT:** Go to the next channel (quadrature and/or double resonant coils).

The other tabs contain additional information for service and information purposes:

- **Modules:** Contains a list of installed preamplifier and active detuning modules. For each module, the name, the current operation mode and the activated RF power limits are displayed. The following operation modes are used in MRI applications:
  - **dec:** This (default) mode is indicated for all modules, that are used for transmission only or that are unused.
  - **obs:** This module is in the observe mode and is used for data acquisition.
  - **wobb:** This mode indicates, that a module is currently used to tune/match a RF coil.
  - **crp:** This mode indicates, that a module is used in the operation mode for cryogenic cooled RF coils.
  - **emStop:** This mode indicates, that a module has encountered an emergency stop, i.e. because of power limit violation.

- **Devices:** Contains a list of all devices detected at that moment by the automatic hardware identification system (HWIDS). The enumeration of the HWIDS ports 1 – 8 are assigned to the following devices. These are:

#1	Socket interface hardware description	permanently connected
#2	RF socket »TR 1H«, grey label	present when a RF coil is connected
#3	RF socket “TR BB”, blue label	present when a RF coil is connected
#4	RF socket “RX only (1)”, orange label	present when a RF coil is connected
#5	RF socket “RX only (2)”, orange label	present when a RF coil is connected
#6	Gradient coil	connected gradient coil
#7	Shim coil	connected shim coil
#8	Magnet	permanently connected
#9, 10	Not used in MR instruments	

- **Service:** Information on possible error messages. It contains additional information about the hardware and firmware versions of the preamplifier stack.

- **More:** Toggles the display tabs Devices and MAS (MAS: magic angle spinning, not used for MRI).

11.5 Tuning/Matching RF Coils

Depending on the type of the RF coil, tuning and matching of the coil is required when the load of the sample has changed between consecutive imaging or spectroscopy studies.

Tuning shifts the resonance frequency of the coil, while matching adapts the impedance of the coil to the impedance of the transmission/reception chain.

Correct tuning and matching reduces the reflection of RF power during transmission and increases the sensitivity (SNR) during signal reception. It is therefore most important for the coil receiving the signal and less for the transmission coil in a cross coil configuration.

For transmission coils in a cross coil configuration, a mismatch of the transmission coils results in a small increase in RF power needed without any impact on the image quality, because the RF Reference Power calibration (see ParaVision Manual) is done under the mismatched condition resulting in a higher Reference Power. The power required for the flip angle used in the MR experiment is then calculated based on the Reference Power and therefore, the desired flip-angles are still correct. The latter are of relevance for the MR experiment.

Tuning and matching of a RF coil needs to be performed exactly with the sample and setup that is used when scanning. The so called “wobble curve” is displayed on the RF interface display as soon as the wobble process has been started in ParaVision. The example below shows different situations:

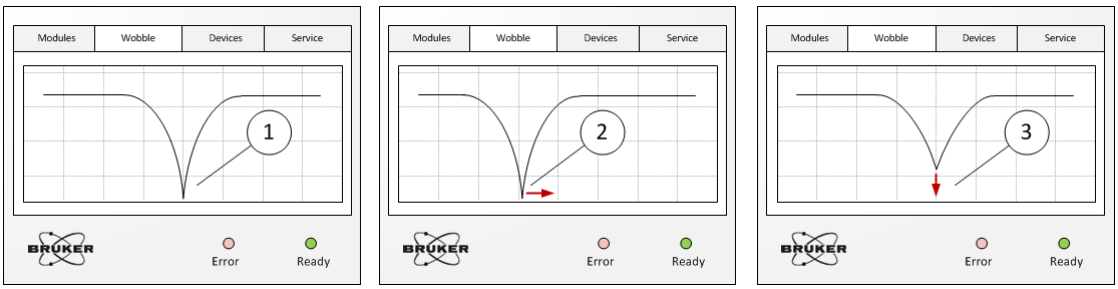


Figure 11.4: Wobble curves on the RF interface display

Pos. No	Description
1	The RF coil is correctly tuned and well matched
2	The RF coil is detuned (off-resonant), but well matched => change the tuning of the coil
3	TH RF coil is tuned (on-resonant), but miss-matched => change the matching of the coil

The following sub-chapters provide the general workflow for the tune procedures of different families of RF coils. Please check the coil-specific user manual for dedicated procedures that are not described in this manual.

11.5.1 Linearly Polarized RF Coils

This description applies to the following types of RF coils (examples):

- linearly polarized (LIN) volume coils, for example RF RES 400 1H 089/060 LIN or
- double resonant coils with the extension LIN/LIN in the item descriptionor
- linearly polarized surface coils, for example RF SUC 400 1H ID 030 LIN

Although the coil can be tuned and matched inside or outside the magnet bore, it is recommended to tune/match the coil while it is already loaded with the sample and in its final position inside the magnet.

Tuning/matching instructions:

1. Connect the RF coil at the corresponding socket of the RF interface

2. Start the tune/match from ParaVision.
3. Adjust and optimize the tune and match condition using the tune and match knobs of the RF coil (labeled T or M)
4. Stop the tune/match via the RF Interface Display or in ParaVision.

11.5.2 Circularly Polarized RF Coils

This description applies to the following types of RF coils (examples):

- Circularly polarized volume coils with active detuning, for example RF RES 400 1H 112/086 QSN TR AD.
- Circularly polarized transceiver volume coils, for example RF RES 400 1H 075/040 QSN TR.

Although the coil can be tuned and matched inside or outside the magnet bore, it is recommended to tune/match the coil while it is already loaded with the sample and in its final position inside the magnet.

Especially RF coils with active detuning are best to be tuned/matched while the separate receive-only coil and the sample is already in its final position inside the magnet.

1. Connect the RF coil at the corresponding socket of the RF interface
2. Start the tune/match from ParaVision.
3. Adjust and optimize the tune and match condition using the tune and match knobs (labeled T or M) of the first channel indicated by yellow rods and labelled “yellow” in the RF Interface Display.
4. Proceed the same way with the second channel indicated by green rods and labelled “green” in the RF Interface Display.
5. Stop the tune/match via the RF Interface Display or in ParaVision.

11.5.3 Cross Coil Configurations

The most common cross coil configurations and the corresponding tune/match properties are listed in the following table:

Excitation coil		Detection coil	
Description	**T/M**	**Description**	**T/M**
Volume Coil with active detuning	yes	Quadrature (circularly polarized) Surface Coil, with integrated pre-amplifier	no
Volume Coil with active detuning	yes	Surface Array Coils, with integrated pre-amplifier	no
Volume Coil with active detuning	yes	Linear Surface Coils, external pre-amplifier	yes

Depending on the polarization of the coil, perform the tune/match process according to the coils described in section *Linearly Polarized RF Coils [▶ 86]* or *Circularly Polarized RF Coils [▶ 87]*. Before the tune/match process of the volume coil is started, make sure that the sample including the local receive coil is correctly installed and inside the volume coil.

11.5.4 Double resonant RF Coils

In general, double resonant RF coils need to be tuned and matched at both resonance frequencies, for example the resonance frequency of the 1H and 13C nucleus. Typical double resonant coils are:

- 1H/X transceiver surface coils, for example RF SUC 400 1H/13C ID=030 TR/TR LIN/LIN
- 1H/X linearly polarized transceiver volume coils, for example RF RES 400 1H/13C 075/040 TR/TR LIN/LIN
- 1H/X volume coils with local X nuclei surface coils, for example RF RES 400 1H/13C 112/086 TR LIN/LIN AD and RF SUC 400 13C ID=030 RO LIN AD

Load a coil with the desired sample and proceed as follows to tune and match these coils:

1. Connect both plugs to the corresponding sockets of the RF interface
2. Start the tune/match from ParaVision, refer to ParaVision manual.
3. Tune/match the first nucleus, in general 1H.
4. Press the NEXT button on the RF interface display.
5. Tune/match the X nucleus.
6. Stop the tune/match on the RF interface display.

Some X nuclei coils do not show any significant load dependency between different loading conditions. In these cases, T/M functionality is not required and is therefore left out in the coil design.

11.5.5 MRI CryoProbes

Please refer to the corresponding CryoProbe (Cryo Coil) on the MRI RF Coil CD and follow all instructions given therein.

11.6 Correcting the Signal Intensity of Phased Array Coils

The signal intensities of different coil elements of a phased array coil naturally differ even when all coil elements are loaded with comparable samples. As a consequence, the image intensity can show visible variation across a homogeneous sample. These hardware based intensity variations can be corrected by the calibration procedure described below.

The calibration factor is called »Array Element Sensitivity« and is saved in the corresponding coil configuration of ParaVision. The Array Element Sensitivity is then automatically applied for every image reconstruction.

Please note, that the Array Element Sensitivities are not applied on the time-domain data or on the time-domain display.

Array Element Sensitivity factors are saved as user specific Coil Configuration.

Array Element Sensitivity factors saved in the Coil Configuration are user specific (ParaVision User Login). For example, Array Element Sensitivity factors determined by Bruker Service using the login NMRSU will not be applied when using other logins.

The Coil Configuration has to be shared and imported by each user, see ParaVision Program & Administration Manual, section “Import and Sharing of Coil Configurations”.

Step 1: Acquire and analyze the calibration data.

Acquire a set of spin-echo images (MSME method) with a good resolution and good SNR on the specified QA phantom of the coil. The slice positions should be selected such that all coils see comparable portions/distances from the sample and can be single or multi sliced. In general, the correct slice positions for coil calibrations correspond to the slice positions measured for Quality Assurance see coil specific manual.

▶ Reconstruct an uncombined (unshuffled) image and use the ROI tool to analyze the image intensities. Therefore, proceed as follows:

1. Define a small circular ROI signal and locate it for every coil element on the corresponding uncombined (unshuffled) image such that the ROI is at an identical distance to the coil element.
   - ➨ To visualize the coil element position, window the images at a high contrast and use the same window scaling for each unshuffled image. Typically, in each image, a brightest area can be identified representing the location of the corresponding coil element.
2. Define a large noise ROI in a pure noise region that provides the noise as standard deviation within the noise region.
3. Identify the coil element with the lowest (minimum) signal intensity, i.e. channel i_{Min}
4. Calculate the signal ratio and the noise ratio for every coil element according to the following equations:
   - ➨ Signal factor (channel i) = signal intensity (channel i_{Min}) / signal intensity (channel i)
   - ➨ Noise factor (channel i) = noise (channel i_{Min}) / noise (channel i)

In an ideal case, signal and noise factors are comparable. Sometimes, image artifacts can lead to enhanced maximum signal intensities, i.e. around air bubbles. Bruker therefore suggest using the ratio of the noise factors to set the channel specific image intensity correction factors.

The calibration of the coil elements results typically in more homogeneous image intensity distributions. But this always bears the risk of wrong calibration or a resulting reduction of the signal-to-noise performance of the coil. Reset the calibration (set factor 1 for each element) or repeat the calibration in case images appear inhomogeneous caused by different protocols and setup.

Step 2: Save the correction factors in the coil configuration file.

If all factors have been determined, the correction factors are saved. Therefore, proceed as follows:

1. Open the ParaVision Configuration card

2. Select and open the coil tab (1)
3. Select the RF Coil from the list (2)
4. Expand the categories *Coils -> <your array coil> -> Array* (3)
5. Open the category *Element 1 (3a)* and enter the correction factor for this element into the “Sensitivity” field (4). Repeat this procedure for all array elements.
6. Select the main category of the modified coil configuration and press the right mouse button to obtain a context menu.
7. Save the configuration and exit the configuration card.

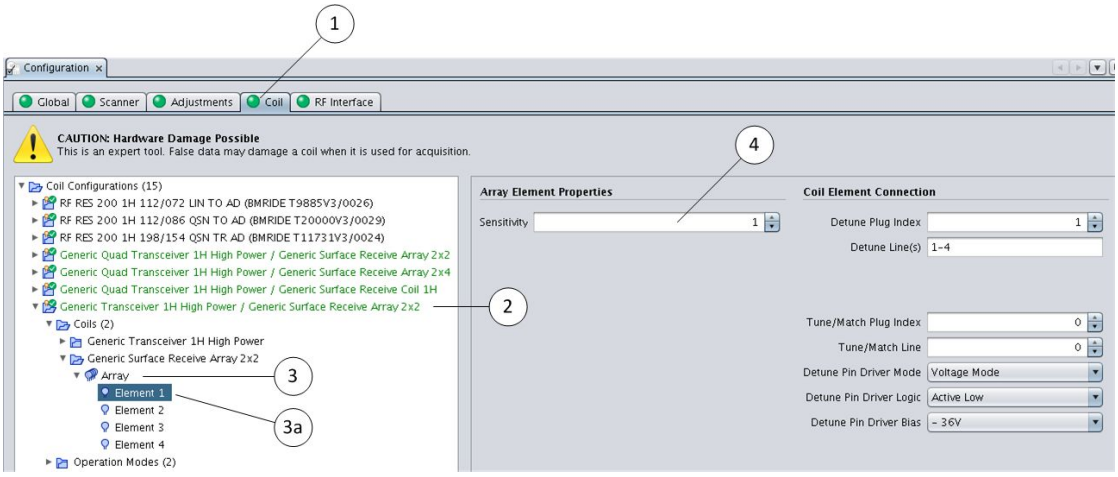


Figure 11.5: ParaVision Configuration card

Pos. No	Description
1	Coil tab
2	Coil configuration
3	Select array coil
3a	Array coil element
4	Sensitivity correction factor for this coil element

2nd Reconstruction of Uncombined (Unshuffled) Images when Duplicating Protocols:

In case a protocol containing a 2nd reconstruction with uncombined (unshuffled) images is duplicated and Array Element Sensitivity factors have just been modified and saved. Die 2nd reconstruction has to be deleted and restarted again in order to use of the recently saved Array Element Sensitivity factors.

11.7 RF Power Limitations

The RF power applicable with a RF Coil is limited by

- the peak power
- the single pulse energy
- the heat created

For any pulse or pulse shape, the numerical relations to check the limits of RF pulses are given by:

Peak Power limitation:	$P(t) \leq P_{Max}$	during the pulse
Energy limitation:	$\int P(t)dt \leq P_{Max} \times T_{Max}$	for a single pulse
Heat limitation:	$\frac{1}{T_{Rep}} \int P(t)dt \leq P_{CW}$	during the pulse sequence with TR (repetition time)

The following figure shows an example of a RF coil that allows 500 W peak power, a maximum time of 5 ms during which the peak power may be applied and a 3 W continuous power. Up to 5 ms, the peak power can be applied. Continuously, 3 W can be applied and in between, the power is limited by the product of power and time (single pulse energy). The longer the pulse in that range, the lower the power allowed.

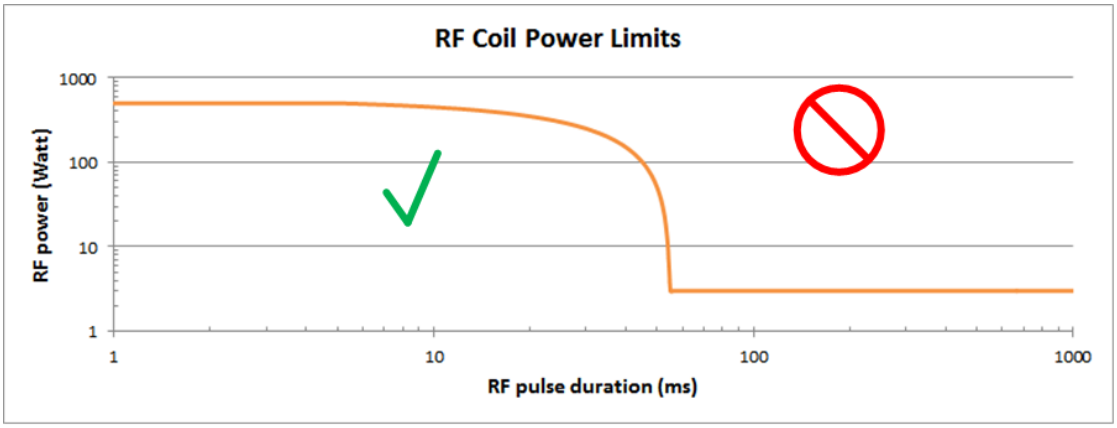


Figure 11.6: Diagram with RF power limits in a double logarithmic plot.

For each RF Coil, the power ratings are programmed within the coil and made available for ParaVision.

ParaVision 6 and higher supervises the applied RF peak power, the single pulse energy and the continuous power of one pulse. Mean power deposition created by several pulses within the repetition time is currently not supervised.

12 MR Instrument Electronics

The following electronic components are located in the technical room. Depending on the instrument type, not all of the components listed are installed.

- Main Electronic Cabinet with spectrometer control electronics.
- Additional cabinet(s) for further options (for example 16 transmit/receive channels) or high power components (for example IECO High Power Gradient Amplifier).
- Dual-loop Heat Exchanger (DLHE) cabinet for magnet compressor and gradient coil cooling or stand-alone gradient chiller.
- CryoProbe Refrigerator
- Platform for the MRI CryoProbe
- Line Power Distribution Panel

12.1 Cabinets with Electronic Components

The Main Electronic Cabinet (1) contains

- the line power distribution (LDU),
- the components for the small signal generation of excitation RF pulses and MR signal reception (TRX 1200),
- the gradient timing unit (GTU),
- the gradient and shim interfaces to generate the signals for the power amplifiers,
- the embedded processing unit (EPU),
- as well as the safety controller that disables various components in case of misoperation.

In addition, most configurations also have the RF power amplifier(s) (RFPA BLA) and the shim amplifier (BSPS) located therein. The gradient power amplifier (GPA) is in a separate cabinet (2). Optional, the instrument can be equipped with up to 16 transmit/receive channels which then require additional space in cabinet (3).

For BioSpec instruments, the dual loop heat exchanger (DLHE 4a) needs to be supported by cold primary water from the house installation. The heat exchanger uses this to provide two secondary water circuits for thermally stabilized cold water to cool the gradient coil and the refrigerator of the USR or US/R magnet.

Figure 12.1: Typical BioSpec configuration: (1) Main Electronic Cabinet, (2) GPA, and (4a) DLHE. Cabinet (3) is optional.

The PharmaScan magnet does not need cooling water so that a stand-alone chiller (air/water) to provide gradient coil cooling water is sufficient (4b).

Figure 12.2: Typical PharmaScan configuration: (1) Main Electronic Cabinet, (2) GPA, and (4b) chiller for gradient coil cooling water.

12.2 Cooling Devices

Magnets of the USR and US/R type are equipped with a dual loop heat exchanger cabinet. On its primary side, the dual loop heat exchanger is connected to the process water and has two secondary cooling circuits. One cooling circuit is used for the gradient coil cooling and one for the compressor of the magnet refrigeration, which is located in the lower part of the cabinet.

The cooling circuit of the magnet refrigeration is continuously running while the operating state of the cooling circuit for the gradient coil cooling is controlled by the operating state of the MR instrument. The circuit is turned on automatically as soon as the gradient amplifier is switched on. Operating the MR instrument without gradient coil cooling is not allowed. During normal operation, no user interaction is required.

The water filling level and the water flow rate must be controlled in regular intervals, see Regular Tasks and Checks and Filling Secondary Water Tank.

Magnets of the US type are equipped with an air-water chiller for gradient coil water cooling. The operating state of this cooling circuit is also controlled by the operating state of the MR instrument. It is turned on automatically as soon as the gradient amplifiers are switched on. Operating the MR instrument without gradient coil cooling is not allowed. During normal operation, no user interaction is required.

The water filling level as well as the water flow rate must be controlled in regular intervals, see the individual manual of the chiller.

NOTICE

The MR instrument is designed for a gradient cooling water temperature of 18±1° C. If a lower temperature is selected:

1. water can condensate,
2. the water temperature can fluctuate and the MR instruments operation can become unstable,
3. the time to stabilize the instrument after switching on the water cooling can be longer.

▶ Do not change the temperature set point of the gradient chiller or of the dual loop heat exchanger below 18° C.

12.3 MRI CryoProbe Platform

If the instrument is equipped with an »MRI CryoProbe«, the cryo-platform to control the CryoProbe is located in the technical room. For further informationen refer to the operating instructions of the MRI CryoProbe.

12.4 Line Power Distribution Panel

All components of the MR instrument are supplied with power via the Line Power Distribution panel (LPD) installed in the technical room. It provides distinguished connectors for all cabinets and accessories. No user interaction is required.

A central power interruption switch is located at the front side of the panel. Use the switch only during service activity.

In case of emergency, use the rotary switch at the *Electric Emergency [▶ 36]* to switch off the instrument.

NOTICE

Connecting power consumers other than the MR instrument to the Line Power Distribution panel or connecting instrument components to other sockets than those provided by the Line Power Distribution panel can lead to ground loops and unstable instrument operation.

- ▶ Do not connect other devices to the Line Power Distribution panel.
- ▶ Do not modify the connections at the Line Power Distribution panel.
- ▶ Do not connect instrument components to other sockets, than those of the Line Power Distribution panel.

13 Cleaning and Disinfection

⚠ CAUTION

Health hazard while cleaning the device (worker protection)

Compliance with occupational safety and health regulations are in the responsibility of the System Owner (responsible body).

- ▶ Before starting to clean the instrument, make sure that radioactivity is completely removed from the instrument and correct decay times have been applied (PET/MR and PET/CT instruments).
- ▶ Wear appropriate protective gear. As gloves, impervious gloves, e.g., latex or nitrile are recommended.
- ▶ When handling or using any cleaner, consult the manufacturer's Material Safety Data Sheet (MSDS) for additional information prior to use.

Cleaning

Use dry cleaning whenever possible or dampen a soft, lint-free cloth with water or a diluted cleaning solution of an all-purpose cleaner and wipe the surface carefully. Do not immerse.

Disinfection

We recommend to use surface disinfection using for example Microbac® forte.

Disinfection with VHP, a vapor form of hydrogen peroxide (H_2O_2), is possible, however, the product lines have not been specifically designed to withstand repeated VHP disinfection procedures under long-term conditions. VHP exposure may lead to surface blistering and corrosion of electrical contacts. It is important that the VHP manufacturer's instructions are read and followed in detail to strictly avoid H_2O_2 condensation; and the VHP exposure interval must be kept as short as reasonably possible.

NOTICE

Material damage of the device

Cleaning of the device with the following chemicals will damage the device.

- ▶ Do not use acetone, ketones, hexanes, acids and alkalis.
- ▶ Do not use alcohols such as for example ethanol, propanol, or isopropyl alcohol (isopropanol) or products, containing alcohols such as Bacillol®.
- ▶ Do not use volatile cleaners like thinner or benzine.

14 Maintenance

This manual provides instructions for use and information on the MR instrument operation. With regard to maintenance, we refer to the System Owner Manual where in section Maintenance, regular tasks, safety and reliability checks, user maintenance actions as well as information on the operational qualification of the MR instrument are provided.

The System Owner Manual is provided as dedicated section on the User Documentation.

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