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MRI Quenching 101 and How You Can Avoid It

Magnetic Resonance Imaging (MRI) machines have become a commonplace diagnostic tool in medical facilities around the world. In the U.S. alone, there are roughly [13,000 MRI systems](#) performing more than [40 million MRI scans](#) every year. There is a good reason for this: not only are they incredibly effective at diagnosing neurological, musculoskeletal, and cardiovascular conditions, but they are also safer than other types of diagnostic imaging equipment that produce radiation, such as X-rays and CT scans.

However, that doesn't mean that MRI machines are without issues. One of the biggest challenges of owning and operating an MRI system comes in the form of quenches, which can cause equipment damage and significant downtime. If proper safety protocols aren't followed, a quench can also pose a serious safety risk.

What is MRI Quenching?

An MRI system uses superconducting magnets to generate powerful magnetic fields to enable high-resolution imaging. However, to remain superconductive, the MRI machine's magnet coils must remain at -4 kelvin (-452 °Fahrenheit) to prevent a loss of superconductivity. This allows a current to circulate indefinitely without generating heat.

To maintain -4 kelvin, the system's magnets are housed inside a sealed vessel called the cryostat. Inside the cryostat, they are bathed in liquid helium, which allows the magnetic field to stay on at all times.

If the coil's temperature goes above the threshold, the magnet will stop being superconducting and will begin resisting the electrical current. The current passing through this increased resistance will generate heat, which, in turn, will cause the liquid helium to suddenly boil off, resulting in the loss of the magnetic field. This is what's known as a "quench."

How Does MRI Quenching Happen?

There are two ways that a quench can occur. The first is due to a disruption or problem with the MRI machine's magnet system. The second is when the emergency Magnet Stop button is activated to deliberately trigger a quench.

If an MRI system quenches on its own, it's due to the failure of one of its components. Because the magnets must be kept near absolute zero, any failure involving the MRI's cooling system, such as the chiller, compressor, cold head, or cryogenic lines, can lead to the evaporation of

excess helium. If the helium levels drop too low, a quench will occur. Once an accidental quench occurs, the system must be carefully inspected to diagnose the exact problem.

A deliberate quench can only occur when the Magnet Stop button is activated. This should only be done if the MRI machine is being decommissioned or in the event of an emergency. For example, if a fire breaks out in the MRI room, then a deliberate quench should be triggered. There are a few reasons for this:

- Emergency equipment made of ferrous metal, such as fire extinguishers and oxygen tanks, can be magnetized and turned into dangerous projectiles.
- Firefighters and paramedics who need to enter the room may not be MRI-safe, which could prevent them from responding promptly to the situation.
- The magnetic field may make it difficult to remove the patient in an emergency situation, for instance, if they are pinned by equipment or trapped in the machine's bore.

Is MRI Quenching Dangerous?

Although quenching can be intentionally triggered to prevent a situation from becoming more dangerous, it can also pose a safety risk in its own right. Because of this, the room should always be cleared before a quench is activated. That said, the following are a few potential risks associated with an MRI quench.

Hearing Damage

The execution of a quench results in an incredibly loud bang. This sound is loud enough to rupture the eardrums of anyone within close proximity of the machine. This can put patients and staff at further risk in an emergency, such as a fire, because they may not be able to hear warnings or instructions to help them escape danger.

Asphyxiation & Cold Exposure

When a quench occurs, helium gas will be rapidly expelled from the MRI machine. Although helium gas is non-toxic and non-flammable, it will displace the oxygen in the room, causing asphyxiation. Because helium is so cold, exposure to helium gas can also lead to hypothermia.

Because exposure to helium gas can be life-threatening, all MRI rooms should be equipped with emergency ventilation systems to safely route any expelled gas outdoors. If the room doesn't have proper ventilation or its ventilation system fails, the gas can build up near the ceiling and then gradually descend.

Air Pressure Hazards

When helium converts to a gas, its original volume will expand by hundreds of times. This means that when a room is filled with helium gas, the air pressure can rise quickly. When such rapid pressure buildup occurs, it can cause panels and fixtures to become dislodged or airborne.

It can also make the doors leading out of the MRI room difficult to open, preventing anyone who's inside from escaping to safety. However, most modern MRI rooms are designed so the door can be easily opened regardless of changes in air pressure.

MRI Equipment Damage

Although the first concern should be the safety of any patients or staff inside the MRI room, a quench can also cause costly damage to the machine. The following are several ways an MRI system can be damaged during a quench:

- **Magnet Coil Damage:** A sudden exposure to heat during a quench can cause the machine's magnetic coils to crack or warp.
- **Mechanical Damage:** The collapse of a magnetic field can lead to imbalanced electromagnetic forces that can cause components to shift or deform, leading to permanent structural damage.
- **Cryostat Damage:** Because helium expands rapidly as it transitions to gas, it can stress the cryostat, leading to leaks or ruptures in the vessel.
- **Electronic Component Damage or Failure:** Abnormal voltages, current fluctuations, and thermal shock caused by a quench can damage power supplies, sensors, and cryocoolers – or cause them to fail completely.

How to Prevent MRI Quenching and Its Dangerous Effects

An unplanned quench can not only be incredibly dangerous but also expensive. If an MRI machine sustains significant damage, it may require extensive repairs or even replacement. Additionally, whether it requires repair or replacement, it could be out of commission for a lengthy period of time. Any kind of downtime can be costly.

Not to mention, once a quench occurs, a substantial amount of helium will likely have boiled off and been expelled. This means that the MRI's helium levels will need to be refilled – and liquid helium does not come cheap. Due to the potential safety risks and possible expense of an MRI quench, the best course of action is prevention. The following are a few steps to take to prevent accidental quenching in the first place:

MRI Safety Protocols to Minimize Quench Risk

Besides designing the MRI room to minimize safety risks following a quench, several safety protocols should be followed to prevent one. For example, there should be no ferrous objects in the MRI room at any time since the MRI's magnets are powerful enough to turn them into dangerous projectiles.

Before anyone enters an MRI room, whether it's staff or patients, they should be screened for any ferrous materials. Any ferrous jewelry or items on their person must be removed. People should also be questioned about any ferrous metals implanted in their bodies. Patients often forget that they have such implants until they are asked about them.

Finally, some clothing is manufactured with metal components. As such, patients should change into MRI-safe clothing before entering.

Routine Maintenance to Avoid Quenches

Although some manufacturers recommend getting preventative maintenance every six months, it's highly recommended that you have your MRI system inspected by a professional every three months. Doing so will ensure that all of the machine's components are working correctly and that helium levels are sufficient. Damaged components could fail, leading to a potential quench. Additionally, the room's HVAC system should be periodically checked to ensure that the emergency ventilation system is working properly.

Safe MRI Operation Requires Expert Training and Support

MRI systems are complex machines. A quench, whether planned or unplanned, can not only cause expensive damage but also pose a potential safety risk to anyone in the MRI room. As a result, only highly-trained personnel should operate or be near your MRI system. It's also essential to maintain your MRI by scheduling routine preventative maintenance checks.

At MXR Imaging, we offer comprehensive installation, preventative maintenance, warranty support, and technical training services to help your facility maintain a safe and effective MRI machine.