

## Certificate of Compliance

### MRI (Magnetic) Compatibility of Flotec Aluminum and Brass Regulators

The Flotec Aluminum and Brass Regulator are Certified to be MRI Safe and MRI Compatible.

**The following is the test report provided by:**

Emanuel Kanal, MD, FACR  
Director, MR Services  
UPMC Presbyterian  
200 Lothrop Street  
Department of Radiology, Room D-132  
Pittsburgh, PA 15213-2582

**Methods:**

The Flotec oxygen regulator submitted for testing was tested for deflection. The oxygen regulator was also tested for torque and artifact generation potential. All testing was performed in a GE Signa® LX 3.0T MR System. Specifications: multi-coil superconducting, actively shielded magnet housed in a 94cm bore; gradient amplitude - 40mT/m and slew rate - 150T/m/s; 8.2.5 M4 software. Using gauss line plots and visual inspection, the location of where the spatial magnetic field gradients were the greatest was determined. This location was marked by color-coded tape.

Using established guidelines\*, an apparatus was constructed to hold the implants for testing. This apparatus consisted of a plastic protractor with a string to hold the implants and a plastic level glued to the top of the protractor. The protractor assembly was attached to a slide mechanism on a plastic rod that was attached to a flat piece of Plexiglas. The protractor was placed far enough away from the rod to allow for free movement of the implants. Using the scanner alignment lights, isocenter in the coronal plane was marked on the rod.

The oxygen regulator was tested with a hand held magnet prior to measurements. No gross ferromagnetic attraction was noted with the oxygen regulator when exposed to the relatively weak hand magnet, and we proceeded with the formal phase of the testing.

The oxygen regulator was weighed on a top loading balance, XL-5K, Denver Instrument Company. The string used to hold the oxygen regulator was weighed using a top loading balance, XL-300, Denver Instrument Company.

All sources of forced air movement were shut off. This included the patient fan inside the bore of the magnet, as well as the gradient cooling fan. The apparatus was aligned in the direction of the main magnetic field and centered in the sagittal plane using the scanner alignment lights. The device was attached to the string and placed at isocenter in the vertical axis as determined by the MR scanner alignment lights. The protractor was leveled horizontally. A landmark was then established. The apparatus was advanced to the location of the maximum gradient change marked previously. The table location, as indicated by the LED display, was documented. After steadying the implant, with the string at 90 degrees, the device was released to move freely and the deflection angle was recorded. Three separate measurements were taken and recorded.

Torque was measured on this single device by positioning it perpendicular to the orientation of the MR scanner's magnetic field/magnetic lines of force while on a sheet of plate glass at magnet isocenter and grossly observing for any rotational realignment forces attempting to reestablish a parallel orientation.

Flow measurements were examined on the Flotec oxygen regulator, S/N 421763 model in two separate locations: 1) Location #1 just inside the magnet bore opening, and 2) Location #2 at the entrance to the magnet room (approximately 33 feet away from the magnet bore opening). Measurements were taken with an attached Sherwood MR compatible post valve (tested by our facility at 3 Tesla) in the "On", or fully opened, position. Flows were set at the oxygen flow rate control unit at the side wall of the MR scanner and measurements called off by a second individual blinded to the flow settings at the wall unit control location. Flow measurements were made using a standard flow meter positioned >10 feet from the magnet bore entry location. Of that which was set on the single oxygen regulator so tested (Flotec oxygen regulator, S/N 421763) setting

To test for possible artifacts within MR images obtained while this oxygen regulator was in use, two separate scans were performed to determine if the presence of the oxygen regulator in the magnetic field created any degradation in the MR images. The GEMS nickel doped spherical phantom, in the loader, was scanned, using gradient echo sequences with an echo time of 20 milliseconds, flip angle of 45 degrees, repetition time of 200 milliseconds, 24cm x 24cm field of view, 5mm slice thickness with a 1mm gap. This sequence was performed twice; once with the post valve/oxygen regulator located at the bore entry location and then again with these devices removed from the bore/bore entry position.

\*Standard Test Method for Measurement of Magnetically Induced Displacement Force on Passive Implants in the Magnetic Resonance Environment, 6. Apparatus

## Results:

The Flotec Oxygen Regulator S/N 421763 demonstrated 21 degrees of deflection on the deflection angle test; this is below the 45-degree threshold necessary for claims of MR safety/compatibility. Torque test was grossly negative for this model/device. No significant artifacts were observed in the image with this oxygen regulator/attached post valve positioned at the magnet bore entry location. Signal to noise measurements of the phantom with the above-noted post valve still attached to the Flotec Oxygen Regulator, S/N 421763 at the bore entry location, were comparable (150.6 for the baseline and 152.6 with the devices at the bore entry location) and well within one standard deviation of noise measurements (noise measurements were 23.18 for the baseline and 22.8 with the post valve/oxygen regulator at the bore entry location). Flow rates measured at increments of  $\leq 1$  l/m throughout the range of 0 to 6 l/m at both locations #1 and #2 measured consistently within roughly 0.5 l/m of that set on the wall control unit. Thus, no alteration of flow rate/function was identified or observed for this oxygen regulator S/N 421763 that appeared in any way dependent upon or modified by the presence or absence of the static magnetic field and static spatial magnetic field gradients of the 3T MR scanner.

## Conclusions:

It is my opinion that the present submitted Flotec Oxygen Regulator S/N 421763 model tested does meet the criteria for both MR safety as well as MR compatibility at 3 Tesla when used up to and including at the magnet bore entry position of this system on which it has been tested.

Please note that grossly detectable Lenz's Law related forces when torqued at bore entry and even greater such detectable forces at magnet isocenter are expected and predictable for metallic objects of this mass/geometry, and should not be misconstrued as affecting present definitions of product labeling.

Emanuel Kanal, MD, FACR  
Director, MR Services  
UPMC Presbyterian  
200 Lothrop Street  
Department of Radiology, Room D-132  
Pittsburgh, PA 15213-2582

John David, PHD Thermodynamics  
Director, Engineering  
Flotec, Inc.  
7625 West New York Street  
Indianapolis, IN 46214

September 19, 1995, updated August 3, 2001

Magnetic attraction is an important factor in MRI (magnetic resonance imaging) equipment. MRI equipment have magnets that are so powerful that they can pull steel items across the room into the magnet. So, it is important that the magnetic attraction of the items in the room be small.

It is desirable for people on oxygen to bring their breathing equipment with them into the MRI room. This can be done if the breathing equipment is non-magnetic, e.g. an aluminum cart, and aluminum tank, a brass or aluminum post valve and an aluminum regulator. However, our regulators are not entirely aluminum. Some critical parts of Flotec regulators are made of "non-magnetic" stainless steel that becomes magnetic from processing the material. So, it was necessary to verify how much magnetic attraction our regulators will experience.

The RR830-100P1 is typical of our aluminum regulators and has about as much magnetic material as any of our aluminum regulators. The magnetic attraction of the RR830-100P1 measured at 0.0578 ounces in a uniform magnetic field of 290 Gauss. Typical hospital MRI magnets can have a magnetic field as large as 3 Tesla, which is equivalent to 30,000 Gauss. The magnetic attraction of the regulator next to a 3 Tesla magnet should calculate to be about 5.98 oz. assuming a linear relation to static field strength, even if it were next to the magnet.

In conclusion, the magnetic attraction of Flotec aluminum regulators is small. There should be no problem with the regulator being drawn into the magnet of hospital MRI equipment, especially since the regulator is attached to the post valve and tank.

Test to determine magnetic attraction in strong uni-directional (DC) magnetic fields. Test using a friction free torsion balance to determine attraction in known magnetic field. Circulated 50 amperes DC in 632 turn, 12 1/4" mean diameter coil having a measured field strength of 290 gauss at the CG of the Regulator Positioned above the coil. System carefully balanced prior to energizing the coil then added weights to re-balance with attraction of magnetic field. 290 Gauss, Balanced at: 1640 milligrams

$1000 \text{ gauss} = 3.4482 \times 1.640 \text{ Grams} = 5.655 \text{ Grams at } 1000 \text{ gauss } 290 \text{ gauss}$

$1 \text{ Gram} = 0.03527396 \text{ Avdp. Ounces} \times 5.655 = 0.19947 \text{ oz. @ } 1000 \text{ Gauss Field}$

At 10,000 Gauss Magnetic Attraction = 1.995 oz./10kg.  $\pm 5\%$ .

Regulator Weights 14 1/8 oz.

$1.995 \text{ oz.} = 0.41412 \text{ or Attraction} = 14\% \text{ of weight of regulator. } 14.125 \text{ oz.}$