Trivial Defeat of a Balanced Magnetic Switch

John T. Jackson, Jr., MS
Jackson Research
www.jrmagnetics.com

Abstract

Balanced Magnetic Switch (BMS) vulnerabilities render it defeatable by trivial means. A detailed description of the most common BMS device and procedures germane to its defeat including a method of how to design defeat tools and apparatus for analysis of any common BMS based upon glass reed technology are provided.

Introduction

The patent for the first Balanced Magnetic Switch or BMS, otherwise known as the Triple Bias Switch, was issued to Holce [2] in 1980 as a "High Security" device intended for use in physical electronic high security systems designed to protect high value targets. It was supposed to replace other magnetic sensor devices with known vulnerabilities. The intent was that it should be invulnerable to any kind of defeat or tampering so that even if its presence was known, there was no effective way around it. During its development, it probably could have met that criteria. However, by the time the patent issued, it was already obsolete and quite vulnerable to defeat by trivial means as was its predecessor. To see how this developed, we need to examine historical aspects that affected the technology and its perception. Then, we will take a detailed look at how it works and why it is so easily defeated. A laboratory set up will be described whereby anyone can tailor a defeat tool targeting any manifestation of the BMS switch based upon glass reed technology or any technology operating on a similar principle.

History

The first patent for a glass reed switch was filed by Elwood in 1940 [1]. The basic Form A device consists of two magnetic wires in close proximity separated by a small gap as shown in Figure 1. It is a Normally Open Single Pole Single Throw switch. The switch is closed when in proximity to a magnetic field, generally provided by a permanent magnet in security sensor arrangements. The two blades attract each other under the influence of a magnetic field. The bare Form A device is actuated in the presence of a sufficiently strong magnetic field making a closed circuit. Although the actuating field zones tend to be lobed, the device is basically omnidirectional.

The original magnetic sensor used on doors and windows for physical electronic security systems was a simple glass reed in combination with a single ferrite or Alnico permanent magnet. A typical application embeds the glass reed switch in a plastic shell of which two common embodiments of this approach are shown in Figure 2 and Figure 3. The moving part is always a permanent magnet. The switch side is connected to the security system by two conductors. Obviously, shorting out the two conductors makes the switch appear secure whether or not the switch is open or closed.

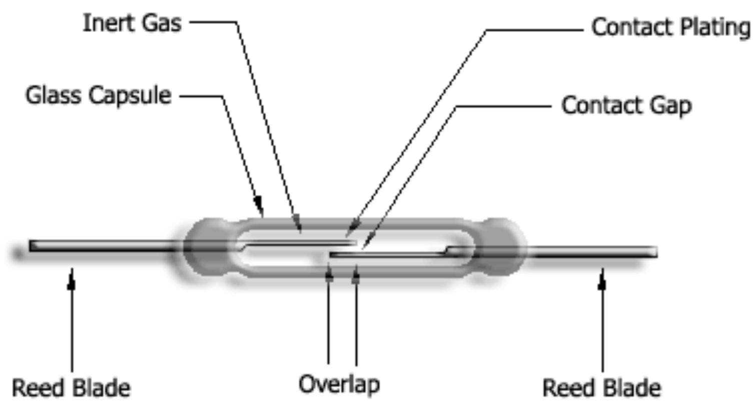


Figure 1: Form A Glass Reed Switch Architecture

This combination is still used in "Home Electronic Security Systems" today. Since it is frequently inconvenient to access the lead wires, it is quite common to find electronic security systems using this type of sensor breached by taping a permanent magnet onto or near the sensor switch allowing opening of the door or window, to which the sensor magnet is fixed, without detection. It is called the "Refrigerator Magnet Defeat" technique. These "singles" or "bullets", Figure 2, as they are sometimes called, are only an inconvenience to a professional. The surface mounted version is shown in Figure 3. These endemic devices obviously have no place in any "High Security" installation.

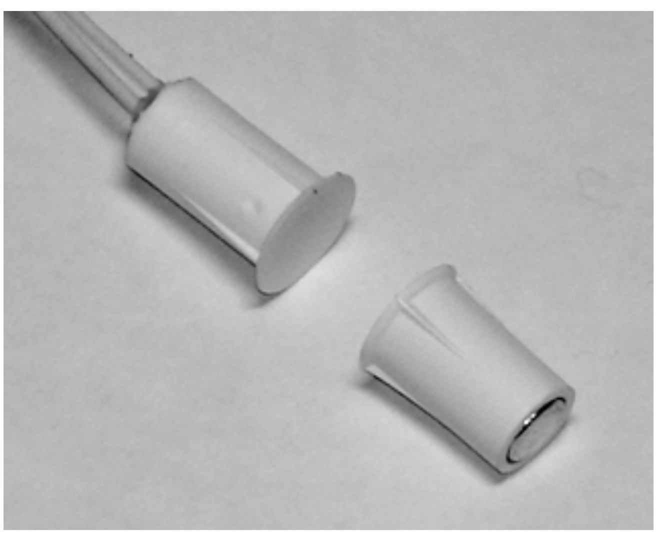


Figure 2: Typical single glass reed and permanent magnet security sensor or bullet.

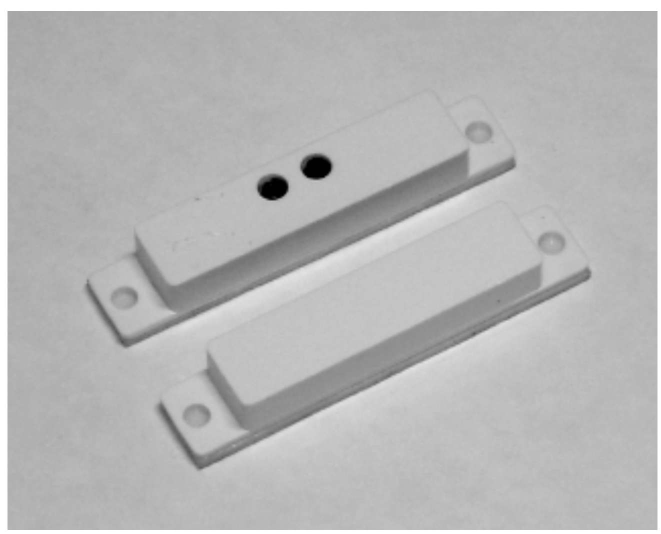


Figure 3: Common surface mount security sensor typically seen on doors and windows.

The BMS was invented by Holce to address this vulnerability. It should not be surprising that it was defeatable by a similar trivial technique by the time the patent issued. New advancements in the field of permanent magnet materials became the nemesis of the Holce

BMS. The two most common permanent magnets, prior to rare-earth magnets, were Alnico and ceramic ferrites. Ferrite magnets were quite popular because their cost was dramatically less than Alnico, being a cobalt alloy. These two materials were obvious choices for the BMS invented by Holce. It is unclear if Holce knew anything about the new rare-earth permanent magnets. He never mentioned them in any of his work. The first rare-earth permanent magnets became public during the same time period as Holce development work. In those days, rare-earth permanent magnets were Samarium Cobalt alloys. They had been developed at Wright-Patterson Air Force Base, declassified and released to the aerospace industry during the 70s just prior to the Holce patent issue date, 1980. Obviously, they were too expensive to be considered for general commercial applications. However, sacrificing security as a compromise against cost violates the fundamental concept of the BMS. Holce made the right choice for a commercial item, but the BMS has never been one. And, it is the rare-earth magnets that made his invention obsolete by the time the patent issued. We will see why later.

To complicate matters further, magnetic apparatus design was usually limited to slide rules and hand calculations. Calculators were a new item. Computers were usually limited to the aerospace industry and not available to the general public. Computer aided design was in its infancy. There was no finite element magnetics software. Obviously, numerous variations made in a prototype shop were cost prohibitive. Detailed numerical analysis by hand was time prohibitive. Consequently, there was considerable trial and error without a clear understanding of how those devices behaved from any analytical point of view. Even with the issued US patent, the actual manufacture of the original Holce device was shrouded in secrecy, requiring a complex bias magnet adjustment during the manufacturing process.

Shrouded in mystery and fighting an up hill battle all the way, Holce finally convinced the US government to use his invention. All of the original US government specifications [5] were written around the Holce device from a purely operational point of view and remain essentially unchanged. Some Lockheed security documents make reference to original device specifications. The present day device is literally identical to its very first manifestation with changes only in its packaging. Over time, the BMS High Security Switches became known as the "First Line of Defense" in modern electronic security systems.

How it worked was obvious the moment I saw it which led to the first alternative [3] that was unique while actually meeting all of the Federal device specific specifications [5]. It became the vehicle for my research into the next generation of BMS technology. The next technology became the basis for my Master's Thesis [6] at the University of Nevada, Reno and another patent [4]. The new technology creates a BMS without any reliance upon glass reed technology. My thesis exposed some of the existing BMS vulnerabilities in graphic detail and hinted at a special defeat tool referred to as “defeat keys” and referenced the invulnerability of my new technologies to it.

Once my first BMS patent [3] issued and the Holce patent ran out, several other companies introduced clones. There are several on the market. They are all based upon the same underlying principle: triple biased glass reeds. They are all vulnerable to the defeat keys I have been selling as “Defeat Sticks”.

The Specifications

All Federal and UL specifications call out a small zone adjacent to the face of the fixed switch which is a dead zone. The switch is actuated/safe/secure when the actuator magnet assembly is between roughly 0.60 inches down to roughly 0.20 inches from the switch face. Closer than 0.20 inches sets off the alarm. This dead zone is its guaranteed vulnerability. It was detrimental, but sold as a feature by marketing people and written into all of the Federal specification documents as well as the latest UL 634 specification.

All High Security Balanced Magnetic Switches, BMS, based upon "Glass Reed" technology, regardless of architecture, can be easily defeated by trivial means. In fact, most BMS that can be characterized by 2-D magnetic field analysis, as opposed to "inherently 3-D" magnetic field analysis, can be defeated by a variety of trivial means. This is partly due to the fact that most existing BMS devices are either clones of the original Holce BMS device or a derivative of the under lying concept embodied in the original Holce patent [2]. The basic objective was to prevent defeat by a single magnet ignoring the fact that it was always defeatable by a copy of its own actuator magnet.

To make matters worse, the new UL 634 specification is both designed around the Holce device as well as designed to exclude it in a combination of contradictory requirements. The UL specification was lobbied by the electronic security industry's corporate executives with total disregard for anything technical. It represents fundamentally a war of specifications intended to include certain products while excluding others. One shining example is the requirement that all BMS must contain rare-earth magnets excluding all ferrites and Alnicos which obviously targets the Holce BMS. The UL 634 specification is intended to suggest that any BMS that meets its requirements is somehow undefeatable. This is simply not the case. It is a political document in its entirety imparting a false sense of security.

The UL 634 specification suggests a means to manufacture a "Defeat Stick". It suggests that any BMS that can pass this test is impervious to this form of attack. It is quite possible to design a BMS that passes these provisions and can still be defeated by a "Defeat Stick" not anticipated within the scope of the document. Here again, it produces a false sense of security. There are no known devices utilizing glass reed technology that are impervious to this form of attack. There is one manufacturer using a glass reed alternative and claims to be impervious to this form of attack. This is also not true.

One caveat is the inclusion of magnetic shielding by some manufacturers to protect against certain types of defeat attack. One such example is the use of a U shaped shield. It is neither novel nor effective. Since the Holce BMS is defeatable by its own actuator [6], magnetic shields were introduced to mitigate that possibility in competing designs. These magnetic sheet metal shields short out the actuator magnetic fields. When the magnetic field becomes sufficiently strong, the shield becomes saturated and no longer effective. Special devices similar to the Defeat Stick can be tailored to penetrate these shields, which is a brute force attack. Reference 6 goes into much greater depth.

The Technology

The basic principle of the BMS is to use three alternating polarity actuator magnets in combination with three polarity-sensitive glass reed switches making the entire assembly resistant to defeat by a single magnet. This requires biasing the glass reed switches so that they are each actuated by low level local magnetic fields. The bias magnet in combination with the glass reed achieves polarity sensitivity to some extent. Form A switches cannot be used here since the biased glass reed switch in combination with the actuator magnet in a secure position would be an open circuit. A closed circuit with the actuator magnet in a secure position requires a Magnetically Biased Form C Double Pole Single Throw switch as shown in Figure 4. When the actuating magnets, whose polarities are in opposition to their corresponding biased glass reed switches, are in the secure position, the magnetic fields around the glass reeds cancel out by vector addition and fall below the actuation threshold. When the actuator magnets are outside the actuation zone, the bias magnets dominate. When the actuator magnets reach the dead zone, the actuator magnets over power the bias magnet's fields and re-actuate the glass reeds.

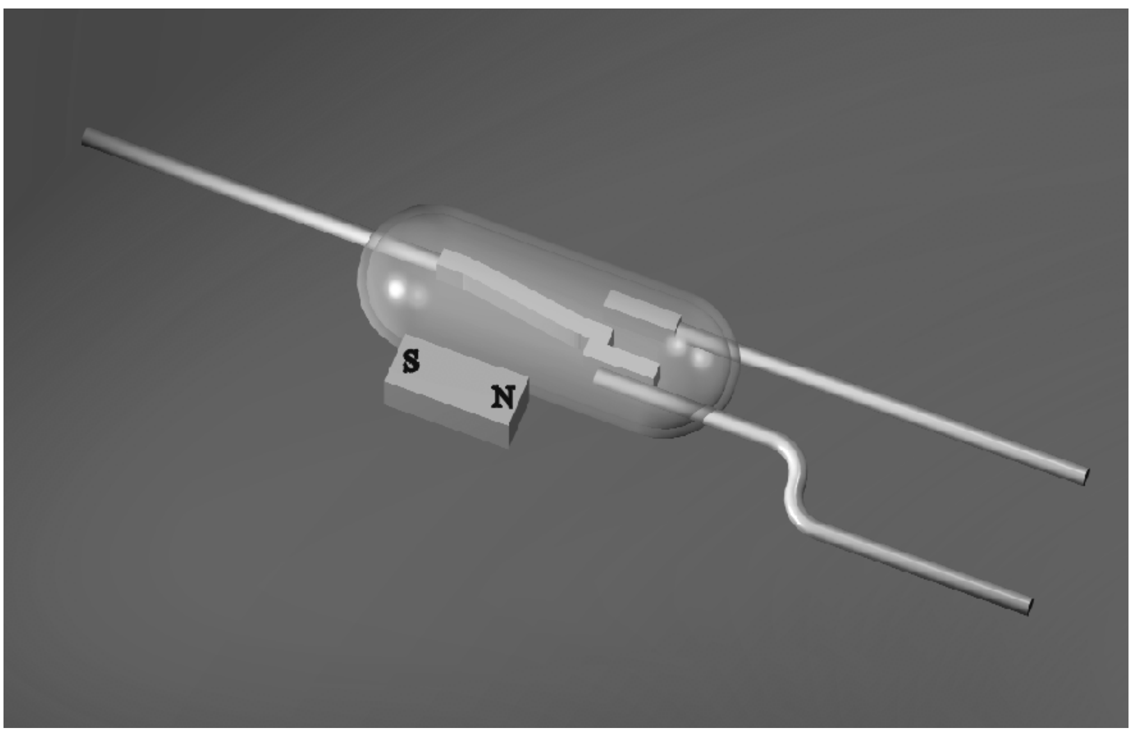


Figure 4: Magnetically Biased Form C Glass Reed Switch

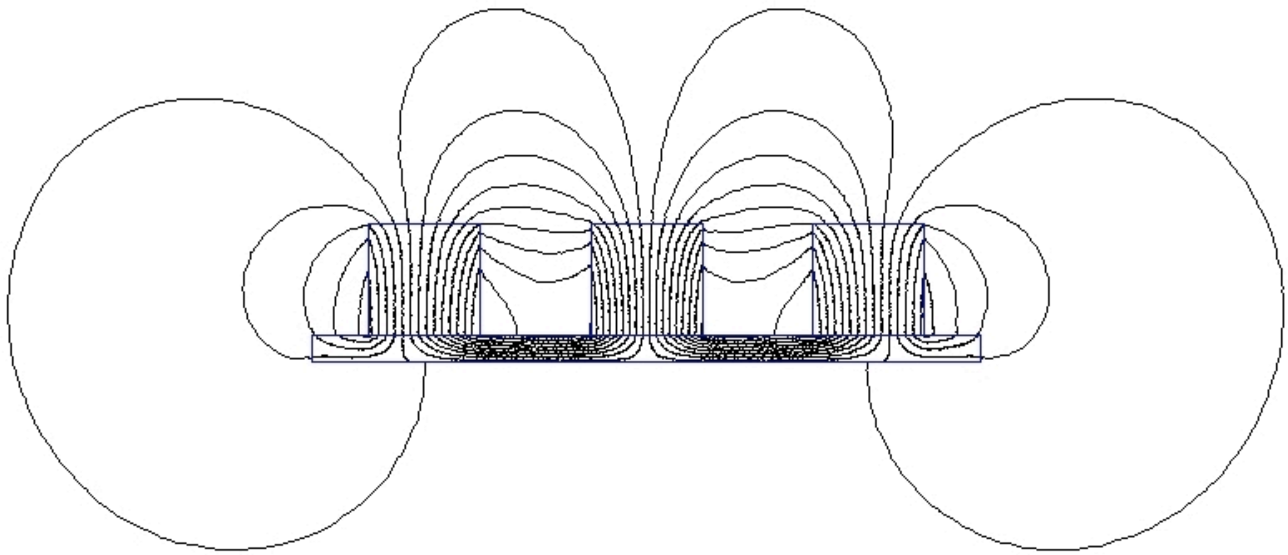


Figure 5: Holce Actuator Finite Element Magnetic Field Plot

Figure 5 is a Finite Element Magnetics field plot of the Holce actuator of the predominant device shown in Figures 6, 7, 8 and 9. It consists of three ceramic ferrite permanent magnets fixed to a sheet metal strip and embedded in epoxy as seen on the right side of Figures 6 and 7.

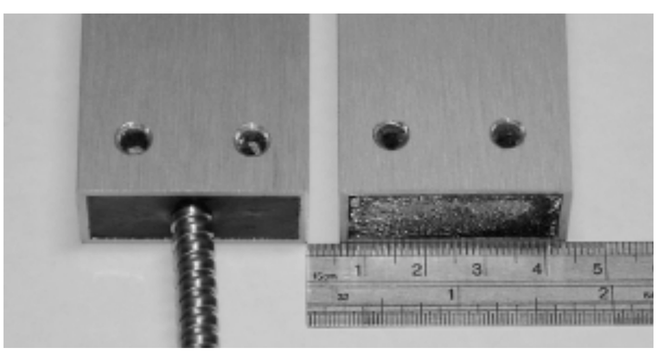


Figure 6: Minimum Actuation Gap Showing Dead Zone measured from the switch face.

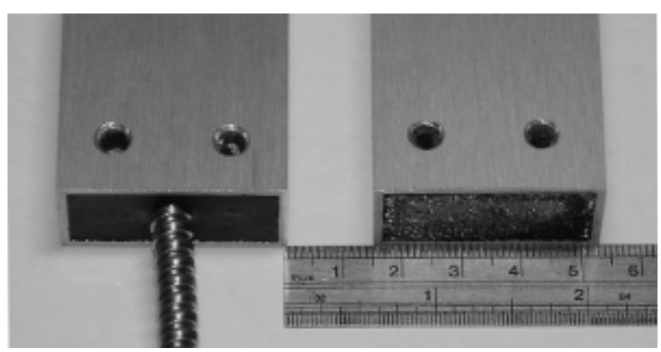


Figure 7: Maximum Actuation Gap measured from switch face.

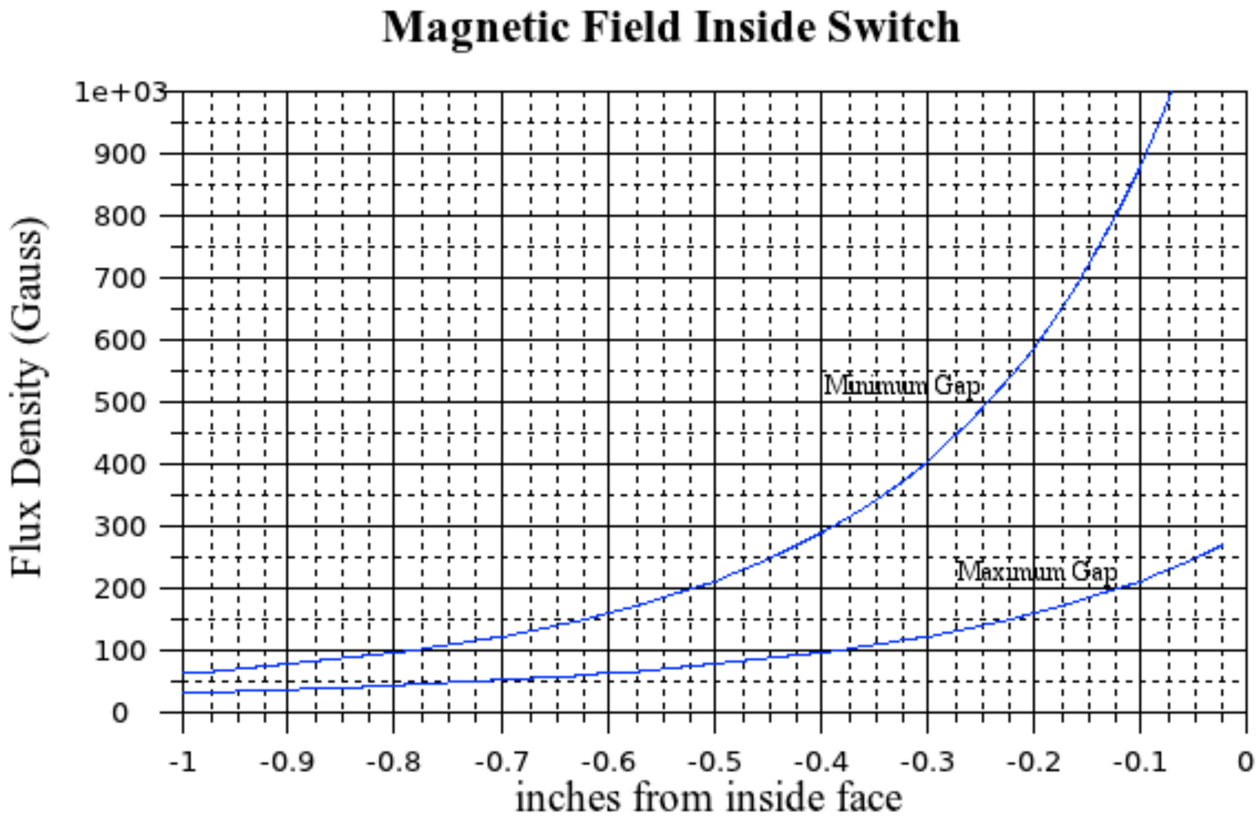
Gap distance is measured from the BMS housing face set as the origin. Gap lengths are positive and position inside the housing is negative. Figure 6 shows the minimum gap, 0.2 inches, for which closer approach sets off the alarm—the "Dead Zone". The upper curve labeled "Minimum Gap" in Graph 1 is a plot of the magnetic field inside the switch when the actuator magnet is at its minimum approach. Figure 7 shows the maximum separation distance, 0.6 inches, from the switch. The lower curve labeled "Maximum Gap" in Graph 1 is a plot of the magnetic field when at maximum separation. The space between these two extremes is the safe or secure position. A gap greater than the Maximum sets an alarm state.

How to Defeat It

The defeat stick fits into the dead zone and makes the switch think it sees its own actuator. The defeat stick is quite innocuous and not usually noticed under casual inspection. This dead zone is an artifact of the bias glass reed technology. The defeat stick is made possible by rare-earth permanent magnets and computer aided design.

The only requirement to defeat the switch is that an actuator narrower than 0.2 inches be introduced into the "Dead Zone" with a suitable magnetic field. The Defeat Stick magnetic field, as measured normal to its center magnet, must fall between the upper and lower curves shown in Graph 1. These two curves are found by measuring the field normal to the center magnet of Figure 5 and off setting it by 0.6 inches to get the bottom curve and off setting it by 0.2 inches to get the top curve with the origin at the face in each case. Clearly the magnetic field will be greatest at the nearest approach and decrease in magnitude as the separation increases. These two curves represent the magnetic field upper and lower boundaries of the secure state inside the switch housing.

Figure 8 shows a Defeat Stick on its side at the actuation face of the switch. Figure 9 shows the Defeat Stick properly positioned in the Dead Zone. The switch registers safe or secure in this position. To further aggravate the situation, the Defeat Stick can be inserted when the actuator is in position without a single glitch.



Graph 1: Maximum and Minimum magnetic fields inside the BMS housing for switch activation measured from the housing face toward the housing back wall.

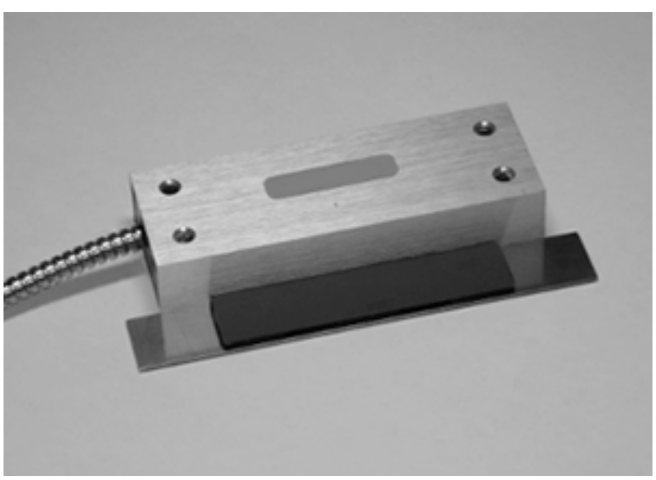


Figure 8: Defeat Stick top view near BMS housing face.

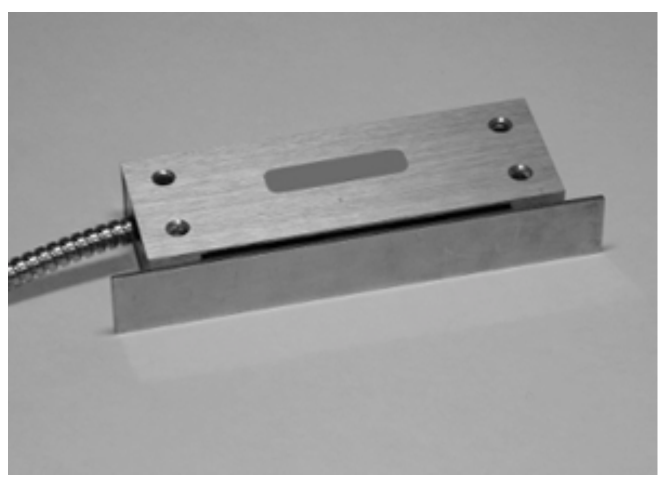


Figure 9: Defeat Stick in position for "live" defeat. The BMS thinks it sees its actuator.

The argument that the actuator magnets should be rare-earth materials to avoid this type of attack is irrelevant, because the glass reeds inside the switch only need to see the actuator magnetic field range between the two curves in Graph 1. The type of permanent magnet material only affects the physical dimensions of the actuator magnets needed to achieve the required actuator magnetic field profile. The defeat stick will always be effective regardless of the magnet material. Making the bias permanent magnets more powerful causes the actuator magnets to be more powerful, but can shorten the actuation range dramatically. The balance between all of the components can only be effectively achieved with computer aided design targeting specific geometries.

The concept of alternating magnet poles from N-S-N to S-N-S only means there needs to be two defeat sticks and a hall sensor to determine which polarity arrangement to use. I have one that looks like a pen and only indicates N or S. Swipe the hall sensor through the gap and pick the appropriate defeat stick. The entire kit fits into a shirt pocket resembling a pen and small ruler.

The Intruder

The most common misconception regarding high security physical electronic installations is that most intrusions are from the outside breaking into the facility. However, nearly 75% of all security breaches are "inside jobs" [7]. In either case, high security is usually focused on the professional intruder who has some expertise defeating electronic physical security systems with the intent that these systems make this difficult, error prone and time consuming. Professionals study their targets and develop a breach strategy. Even a non-professional who is just an employee has all the time in the world to study the system, devise a scheme and execute it at just the right moment. If handled properly, the breach might actually go completely undetected. With the security sensors sabotaged, one could walk in and out unnoticed unless something was actually missing that exposed the breach. The BMS is perfect for this type of operation. Anyone could sabotage these sensors, breach the system completely undetected and later restore the system without raising suspicion. Too make matters worse, the BMS is widely believed to be "undefeatable." Due to this misconception, they are even placed exterior to an egress with the total confidence that no one can pass undetected. The BMS is so highly regarded that other types of sensors are frequently not installed with complete reliance on the BMS. In fact, some video surveillance cameras are only active when triggered by the BMS, so that anyone could walk in and out of a facility at will without ever being seen.

Laboratory Measurements

The test fixture shown in Figure 10 is all non-magnetic on a precision tooling plate with jeweled bearing slides and 3 axis stages. The combined position accuracy is within ±0.001 inches. Gauss meters are laboratory grade to within ±1%. The laboratory environment is kept a 22°C ±1°C with Relative Humidity less than 40%. The standard deviation observed on commercially available BMS was ±20%.

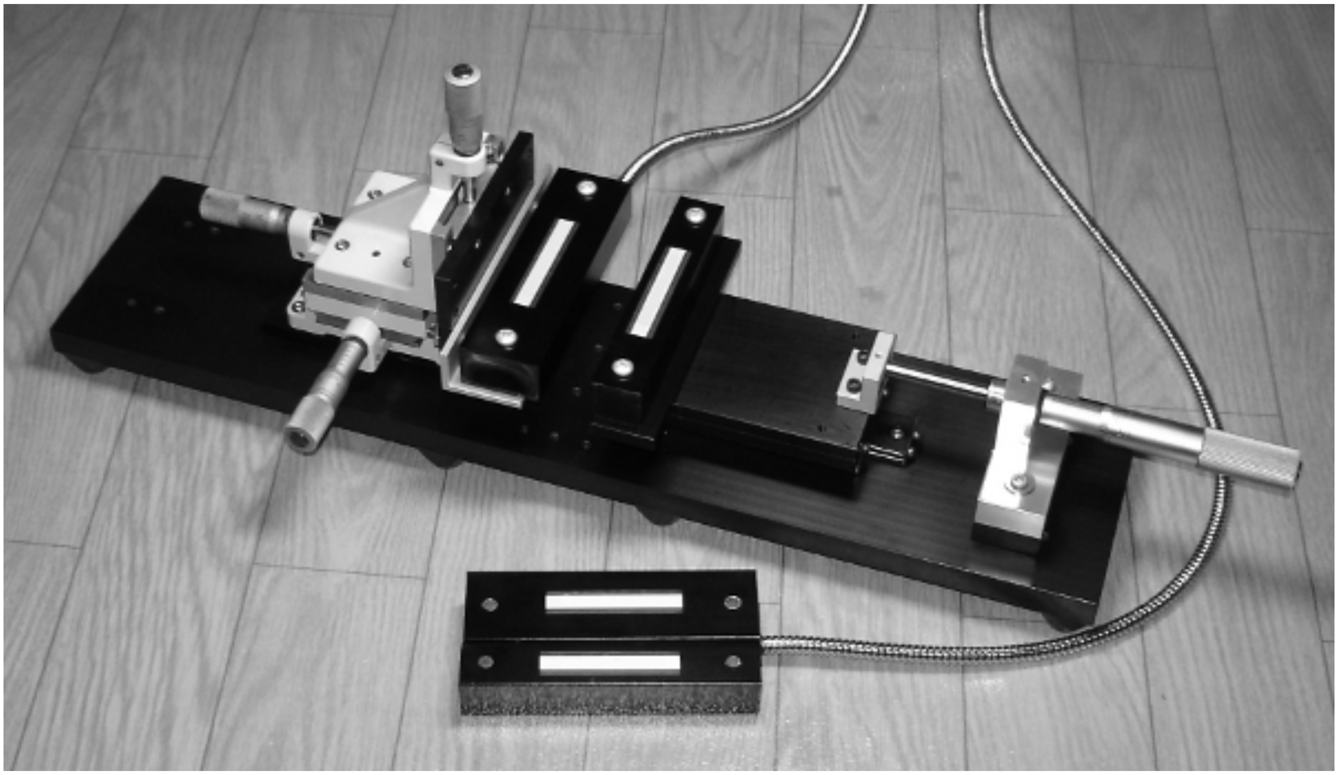


Figure 10: Precision Tooling plate and 3D stages for BMS laboratory grade measurements.

Only the field plot of any particular actuator magnet along the actuator magnet normal axis for any BMS that deviates from the Holce construction and its actuation range is needed to determine the specifications for a new defeat stick using computer aided design. The procedure is to measure and plot the actuator magnetic field and adjust the defeat stick's magnetic field until it fits into the gap with the same profile. All the BMS I tested were defeatable by the same set of defeat sticks. This same principle can be applied to any angle of approach, such as the top or the back. Shielding only means the magnets must be larger to penetrate the shield, which can be taken into account with good computer aided design. Blocking the dead zone is not enough. All BMS consisting of glass reeds have other similar zones of vulnerability as detailed in Jackson et al. [6].

Conclusion

The basic concept behind the traditional BMS as described in the current literature and various specifications is obsolete, highly vulnerable to trivial attack and imparts a false sense of security. A plurality of alternating magnetic poles in combination with glass reed switches, or their equivalent, can always be defeated by trivial means in any physically realizable practical configuration. The "Defeat Key" is the principal form of successful attack. It is virtually impossible to protect against except for a few very specialized cases. The BMS is not an obstacle to a professional intruder. It is only an annoyance. Any alternative technologies considered as replacements for the BMS should be very carefully examined to avoid an unfounded confidence on trivially defeatable or unreliable technologies. The standard BMS utilizing glass reed technology is no better than a home security single and imparts a false sense of security. Anyone, not just professionals, can defeat it trivially, including the janitor.

About the Author

John T. Jackson, Jr., MS received his BS Physics from Oregon State University and his MS Electronic from the University of Nevada, Reno. He is the inventor of the "Wide Air Gap Permanent Magnet Motors" (slotless motor). He has patents in the field of physical security. He is a magnetics specialist and maintains a private research and development laboratory in Hong Kong.

References

[1] Elwood, Walter B., "Electromagnetic Switch", US Patent # 2,264,746, filed 1940.

[2] Holce, Thomas J., "Magnetically Actuated Sensing Device", US Patent # 4,210,889, 1970.

[3] Jackson, John T., Jr., "High Security Balanced Type Magnetically Actuated Proximity Switch System", US Patent # 5,668,533, 1997.

[4] Jackson, John T., Jr., "Balanced Magnetic Proximity Switch Assembly", US Patent # 5,929,731, 1999.

[5] "Federal Specification Components for Interior Alarm Systems, Balanced Magnetic Switches", W-A-450/1 August 28,1990.

[6] Jackson, John T., Jr., "The Jackson High Security Switch and Radio Frequency System", thesis UMI Number 1389436, Copyright 1997 – 1998. PDF copies are available at www.jrmagnetics.com

[7] "Improving Security from the Inside Out, A Business Case for Corporate Security Awareness", copyright 2004 National Security Institute.