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## **New System to Control Magnetic Arc Blow in Welding**

**R. Brian Jones (V)-Newport News Shipbuilding**

### **ABSTRACT**

Welding of magnetized steels has long been a problem in the welding industry. When welding is attempted in the presence of a magnetic field, the welding arc becomes deflected. This phenomena is known as "arc blow." Arc blow can cause significant weld defects, it can reduce productivity, and it is frustrating to the welder. Sometimes weld joint magnetism is so great that control methods must be used to produce a satisfactory weld.

In 1991, Newport News Shipbuilding developed and built six Magnetic Field Negators (patent applied for) for their welding department. Each unit consists of a small hand-carried electromagnet and power supply that operates off any standard 110/120 volt AC power source. The lightweight system is designed to counteract magnetic fields up to 200 milli-tesla (mT) (2000 gauss) across a 13 mm (.5 in) weld joint in 25 mm (1 in) thick steel.

Through laboratory and production testing, the magnetic field negator has demonstrated the ability to neutralize local areas of high residual magnetism, resulting in a considerable reduction of magnetism-related weld quality problems.

### **INTRODUCTION**

High residual magnetic fields usually occur in alloy steels containing nickel, such as HY-80 and HY-100. These fields may enter

a material in various ways - they may be induced during the manufacturing process (i.e. rolling, pressing, burning), or by an external source (i.e. using a magnetic hoist). In addition, residual magnetism is often sporadic, unpredictable and concentrated in local areas of a weld joint.

Arc blow occurs when a welding arc is established in the presence of a magnetic field strong enough to deflect the arc. Arc blow can be so severe that it is detrimental to weld quality. Problems such as excessive spatter, wavy bead appearance, lack of fusion, undercut, and porosity are not uncommon (1). Often these defects must be removed and welds repaired, which can greatly increase welding time and cost. Figure 1 illustrates how magnetism can affect weld quality. The figure clearly shows defects such as spatter, porosity, slag inclusions, and rough weld appearance. Arc blow can also greatly reduce productivity and be very frustrating to the welder.

Magnetic field flux density is measured in tesla (1mT= 10 gauss). Generally, welding will progress normally in fields of 2mT (20 gauss) or less. In fields from 2 to 4 mT (20 to 40 gauss), welding can become difficult. About 4 mT (40 gauss), the welding arc can become unstable and in some cases can even blow out (2). Plate thickness and weld joint configuration are two key factors related to field strength levels. For example, welding on a 38 mm (1.5 in) thick plate with a narrow joint bevel will be more difficult than welding a 13 mm (.5 in) plate with a wide joint bevel.

When welding on thicker plate, the welding electrode has more of its length exposed to the magnetic field. In general, arc blow is greatest in the root pass of an open root multi-layered weld joint (3). After the root pass is welded, the magnetic flux will have a complete path in which to travel from one side

in aircraft carrier modular construction where large amounts of HY-100 were used. Weld joints have been recorded with magnetic fields in excess of 150 mT (1500 gauss). Welding at this level would be difficult - if not impossible - without the use of a control method or special technique.



Figure 1. Effects of a residual magnetic field on the root pass of a weld.

of the joint to the other. Therefore, significant amounts of residual magnetism should no longer be present to affect the welding arc.

### **BACKGROUND**

Weld joint magnetism has been a problem at this shipyard and other steel fabricators for years. In the early 1980's, magnetism problems increased in frequency and severity. This increase occurred mostly

In 1986, the shipyard formed a task group to determine causes, document effects, and develop resolutions for weld joint magnetism problems. From this group, several control methods were developed and have been utilized. Some methods were based on inducing a counter magnetic field of equal strength to neutralize the existing field. Other methods attempted to shunt, or direct the field away from the weld joint.

### Previously Used Control Methods

The following is a brief discussion of some of the previously used methods identified by the task group.

**Neutralizing the Magnetic Field.** Wrapping or looping a welding lead around or alongside the workpiece can help control significant amounts of magnetism. This method induces a field that opposes and neutralizes the residual magnetic field. The welder must determine the direction of the residual field and insure that the induced field opposes it; if not, magnetism will compound and increase. Because the welding lead requires close contact with the joint surface to allow for sufficient magnetic couple, the weld joint should be easily accessible, free from fabrication clamps and/or restraining devices.

**Electrode Manipulation/Technique Adjustment.** The following methods have been used when weak (2-4 mT [20-40 gauss]) arc blow was encountered.

1. Changing the electrode angle.
2. Holding a tight welding arc.
3. Using the gas metal arc process (GMAW) in place of the shielded metal arc process (SMAW).
4. Welding with alternating current instead of direct current.

**Identifying Null Locations.** Using a gaussmeter or magnetic field indicator, a welder locates sections of the joint where the magnetic field changes direction. Welding starts at these null locations and progresses outward until arc blow is encountered. The process is repeated until the joint is complete or arc blow ceases.

**Relocating Welding Ground.** Moving the welding ground closer to the joint being welded can sometimes help control arc blow. However, this technique is effective mostly on weak (2-4 mT [20-40 gauss]) magnetic fields. The ground must be from the same machine used for welding. This method is not practical on large weldments.

**Shunts.** Shunts provide an alternate path for magnetic flux to flow rather than across the root opening. The best shunts are made of low carbon steel and are usually applied to the weld joint as a backing strap. However, shunts do not have to be welded to the joint to be effective. Heat resistant bags can be filled with low carbon steel shot to form a shunt for odd shaped areas. The tighter the shunt is held to the joint, the more effective it will be.

**Degaussing.** Significant amounts of magnetism can be removed using this method. However, because the machines needed to degauss weld joints are relatively large and require a lot of power to operate, their use is limited.

Each of the control methods listed above had their limitations. They were often cumbersome, time consuming, and produced inconsistent results.

#### Commercially Available Equipment

One commercially-available magnetism control device was evaluated. The unit negates the field by inducing a counter magnetic field. After extensive laboratory and field testing, several deficiencies were noted. The control unit suffered from high frequency interference, causing erratic operation. The magnetic coil consists of standard welding cable that is wrapped or looped alongside the weld joint. The unit worked fine on long flat joints; however, it was not practical to use if the joint had fabricating clamps and/or

restraining devices blocking access. Additionally, it was difficult to use on joints in the vertical, horizontal or overhead position.

#### NEW CONTROL METHOD

In 1989, the shipyard sought to develop its own means of controlling arc blow. To be suitable for shipyard use, the system had to meet the following criteria:

1. It should have the ability to produce a strong counter magnetic field.
2. It should be small and portable and allow use on a variety of weld joint configurations.
3. It should be powered by standard 110/120 volt AC.
4. It should be simple to operate.
5. It should be durable when subjected to rough use and elevated temperatures.

Based on this criteria, several prototypes were built and tested. During the testing process, several deficiencies were found that needed to be corrected before the system could be practically used in production. These deficiencies were corrected through an internally funded advanced technology development project.

In 1991, the shipyard completed six magnetic field negating systems for use by their welding department. Each system consists of a small hand-carried magnetic coil and power supply (Figure 2). A counter magnetic field is induced to negate locations of weld joint magnetism long enough for welding to take place. The current model is capable of counteracting a field of 200 mT

(2000 gauss) across a 13 mm (.5 in) root opening in steel plate 25 mm (1 in) thick.

#### Advantages Over Current Methods

While the use of a magnetic coil to control magnetism is not new, the magnetic field negating system has several advantages over previous methods and equipment available.

**Portability.** The total system weight of the coil and power supply is 7.3 kg (16 lbs), making it easy to transport to the job in a small tool bag. The device operates off any standard 110/120 volt AC power source.

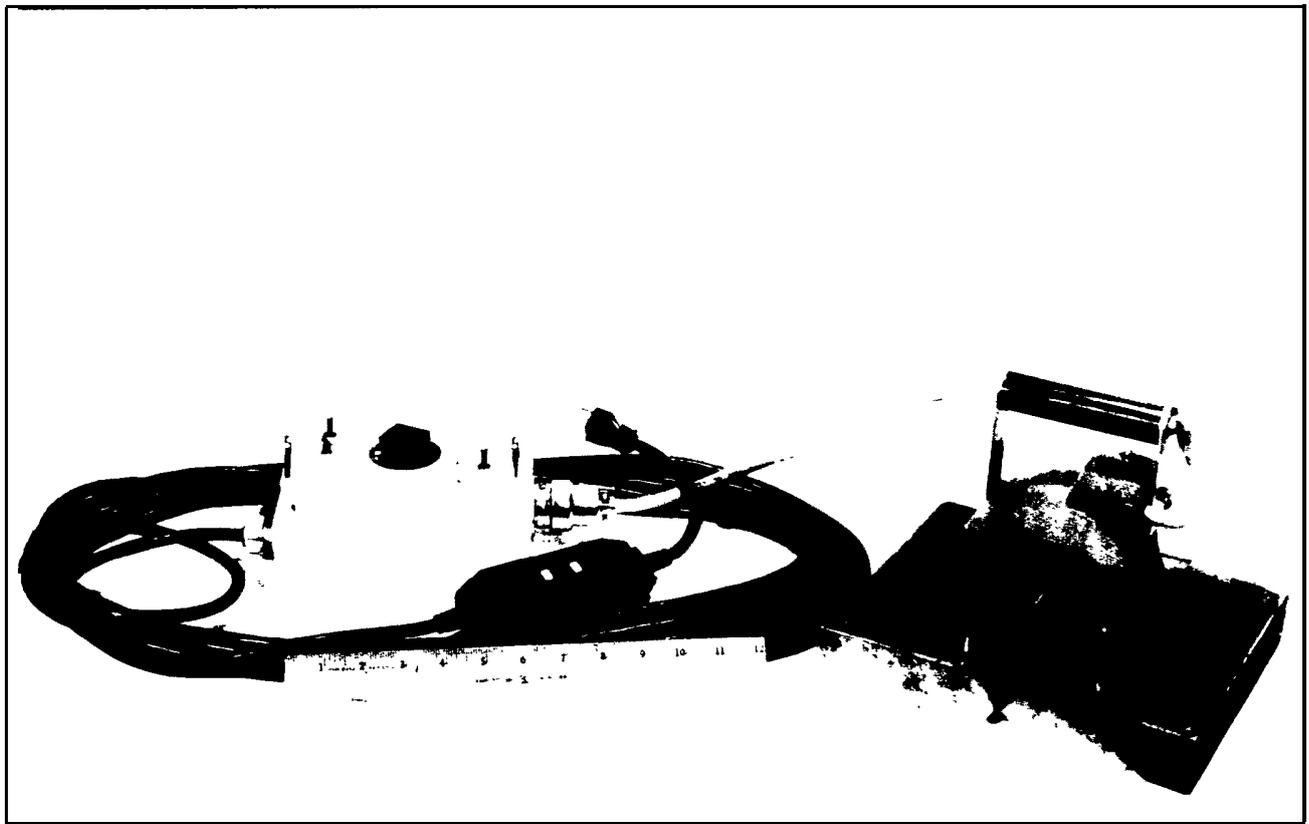
**Coil Size and Configuration.** The hand-carried coil is 165 mm (6.5 in) long and weighs 4.1 kg (9 lbs). It is designed to fit between most fabricating clamps and/or restraining devices. The magnetic coupling surfaces are configured in a manner which enables them to be used on a variety of weld joints such as butt, tee and inside/outside corner joints.

**The Power Supply.** The power supply controls the magnitude and direction of the magnetic flux flowing through the coil. It consists of a variable autotransformer, some simple circuitry, and a field direction switch, all contained in an insulated case. An in-line ground fault interrupter is installed for operator safety. The size of the unit is 180 X 130 X 100 mm (7x5x4) and it weighs 3.2 kg (7 lbs).

#### System Operation

The basic step-by-step process to operate the magnetic field negator is as follows:

1. Determine if the magnetic field negator is needed.



**Figure 2.** Magnetic field negator system (final prototype) with its coil placed across a weld joint mock-up.

2. Place the coil across the weld joint approximately **25 mm** (1 in) from the site where welding will begin. Placement of the device is shown in Figure 3. **The unit can be placed on the back side of the joint if practical.** Placement of the coil depends primarily on joint configuration.
3. Using a gaussmeter, measure the magnetic field strength approximately 100 mm (4 in) in front of the coil.
4. Rotate the current control knob to include a counter magnetic field. Note the movement of the field strength on the gaussmeter. If the field reading is increasing, the current polarity is incorrect. Reduce the control current to zero and flip the polarity switch to the opposite direction. Re-adjust the current control knob. Attempt to get the field strength of the joint as close to zero as possible.
5. Remove the gaussmeter probe from the weld joint.

6. Begin welding. Since the negator does not demagnetize the weld joint, it must remain powered during the welding operation.
7. The system will negate the

field. Plate thickness, root opening and joint configuration are also factors that affect the reach of the coil. Once the welder starts to move beyond the reach of the coil, arc blow will start to be encountered.

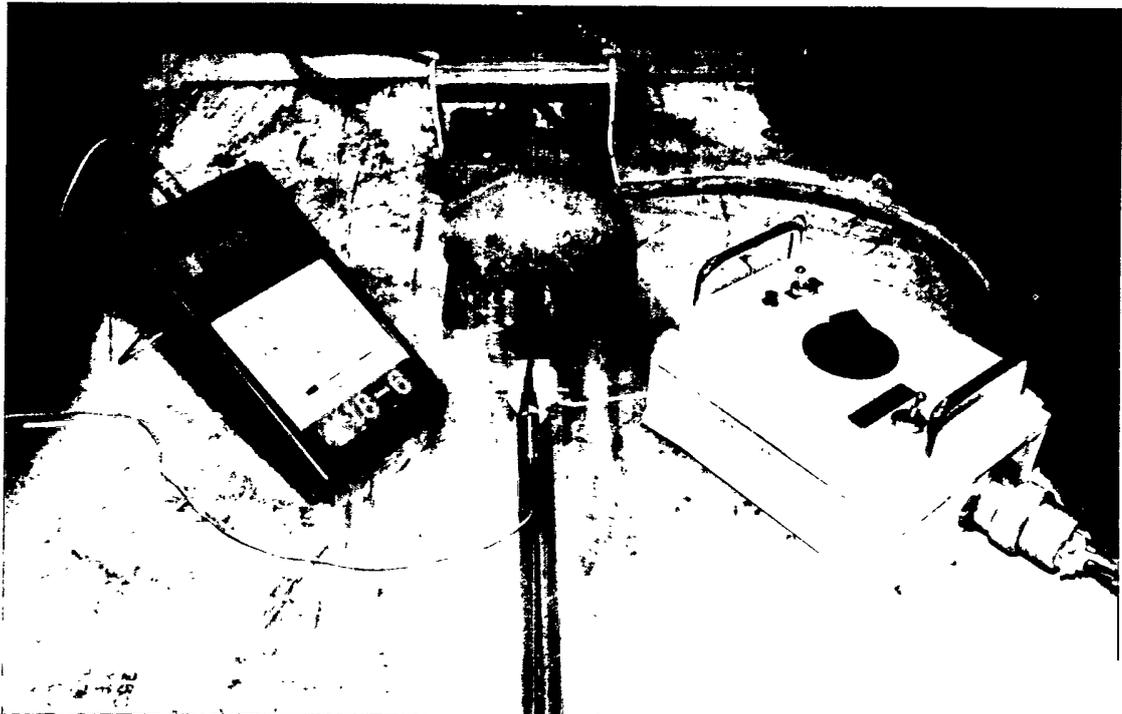


Figure 3. Typical placement of the magnetic field negator and gaussmeter probe across a weld joint.

magnetic field an average of 150 mm (6 in) to 305 mm (12 in) in front of the coil. The “reach” (effective control distance) of the coil will depend on the magnetic field strength of the weld joint. For example, the reach may be 305 mm (12 in) in a 30 mT (300 gauss) field, but only 200 mm (8 in) in a 60 mT (600 gauss)

The coil must then be moved closer to the welding arc, and steps 1 through 6 repeated. These steps are repeated until either the root pass is completed, or arc blow is no longer a problem.

#### Prototype Testing

Testing of the final prototype was

conducted in two locations. A production test was performed onboard ship, while another test was performed in the shipyard's welding engineering laboratory.

**Production Test.** The device was tested onboard the *USS George Washington (CVN73)*. In one case, a magnetized joint on the carrier's main deck was identified by the welding department. This joint had a residual field of 65 mT (650 gauss). Before the magnetic field negator was used, severe arc blow was experienced. After placing the device on the joint, the magnetic field was reduced below 1 mT (10 gauss). When welding resumed, no visible arc blow was detected.

**Laboratory Test.** A test joint was magnetized to demonstrate the field negator's

effectiveness. The joint was fabricated using 25 mm (1 in) thick HY-100 -610 mm (24 in) wide by 915 mm (36 in) long. The joint used was a B2V. 1 (single sided vee bevel) with a 3 mm (.125 in) root opening. A Magnaflux CRV-12 magnetic particle inspection machine was used to induce a magnetic field into the joint. Using a gaussmeter, magnetic field readings were taken every 25 mm (1 in) along the entire joint length. The average measured magnetic field was 35 mT (350 gauss). Then the field negator coil was placed across the weld joint in the location of the highest gauss readings. The field negator was adjusted until a point 150 mm (6 in) in front of the coil obtained a near zero reading. Magnetic field readings were taken again from the base of the coil to 300 mm (12 in) in front of it. The root pass of the test joint was then welded. Figure 4 illustrates improvement in weld

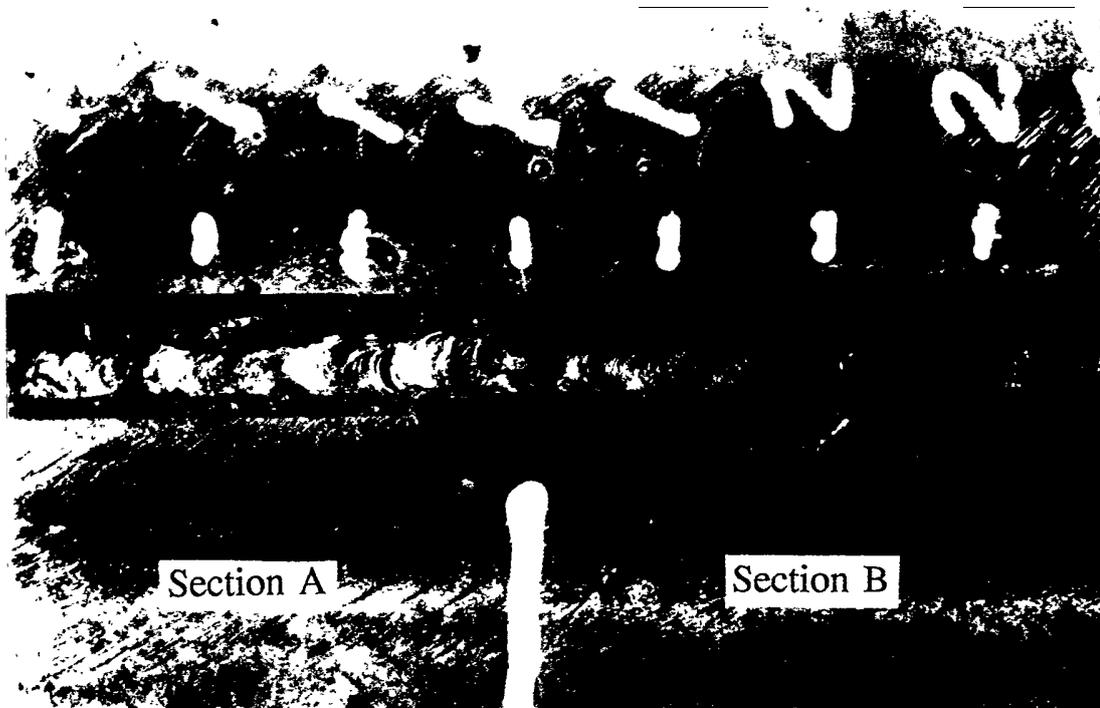


Figure 4. Difference in weld quality between a root pass welded with (section B) and without (section A) the assistance of the magnetic field negator.

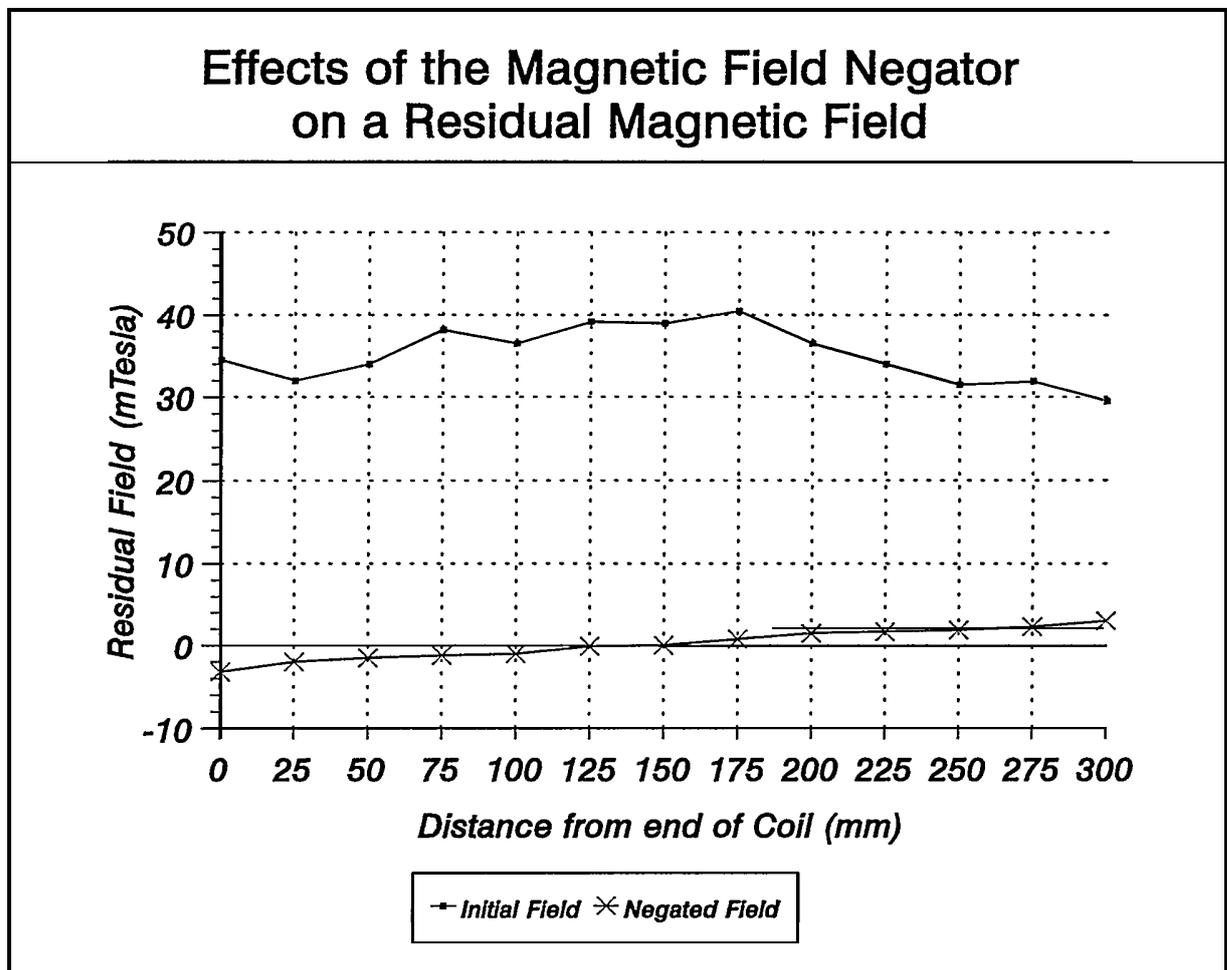
quality when the magnetic field negator was used. Section A of the figure was welded first in the presence of the residual magnetic field; while section B was welded with the aid of the field negator.

**Test Results**

Both the production and field tests produced favorable results. Prior to neutralizing the magnetic field, severe arc blow was encountered when welding was

weld bead appearance. Figure 5 demonstrates the field negator’s ability to significantly reduce the residual magnetic field in the laboratory test joint.

Magnetic field readings do not need to be monitored during welding. Tests have shown that observing the stability of the arc is a good way to determine the needed adjustment to the field negator. However, the residual field should be monitored from time to time with a gaussmeter or field strength indicator to determine when the field changes



**Figure 5.** Comparison of the residual magnetic field before and during use of the magnetic field negator.

attempted. After energizing the field negator, arc blow was greatly reduced or eliminated; resulting in improved arc characteristics and

polarity. In addition, if a gaussmeter is not available, magnetic particle testing powder can be used to determine when the magnetic field

negator has neutralized the residual field in the weld joint. The powder will initially adhere to the sides and root opening of the joint; when the field has been negated the powder will fall out.

### **Limitations**

While the magnetic field negator has several advantages over the previous control methods used, it has its limitations.

1. The system does not degauss the weld joint; once power is removed magnetism will return to the joint
2. The device will only neutralize small lengths (200 mm [3 in] to 300 mm [12 in]) of residual magnetism. It may have to be moved many times if welding a long magnetized joint.
3. Caution must be used when using the device in the horizontal, vertical or overhead position. If power is inadvertently shut off, the unit could fall, possibly causing injury to the operator.

### **CONCLUSION**

Magnetic arc blow can be one of the most frustrating problems a welder can experience. When arc blow is encountered, weld quality can suffer. Until now, control methods or techniques *were* limited, cumbersome, time-consuming, and produced inconsistent results. On the other hand, tests have shown that the new device has the ability to consistently negate local areas of high residual magnetism. After production and laboratory tests were conducted, the following conclusions were drawn.

1. The magnetic field negator is effective in minimizing weld joint magnetism, thus preventing arc blow.
2. The system is lightweight and portable. It operates off any standard 110/120 volt AC power source, allowing use at most any location. It can be used on a variety of weld joint configurations. The system's simple design allows easy operation with minimal training. The device is durable and able to withstand the harsh shipyard environment.

### **REFERENCES**

1. The Procedure Handbook of Arc Welding, 12th edition, Cleveland, The Lincoln Electric Co., 1973, (pp. 3.2-1-3.2-5).
2. P. J. Blakely, "Magnetic Arc Blow - Causes, Effects and Cures". Metal Construction, February, 1988.
3. "Magnetic Arc Blow", TWI Connect, October, 1992.