American Glovebox Society
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Application of Linear Synchronous Motors for Material Transfer in Gloveboxes

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President's Message

By: Justin Dexter

It all started in 1986. A gathering in Keystone, Colorado of individuals from DOE sites, national laboratories, and manufacturing companies spawned the American Glovebox Society. The mission was to standardize glovebox design and fabrication throughout the industry and promote common interests, needs, and goals. Fast forward 30 years, and the AGS is now comprised of hundreds of members from an array of different industries, including pharmaceutical isolators, cleanrooms, hot cells, radio-pharmaceutical enclosures, nuclear gloveboxes, and custom enclosures that keep the world safe and healthy.

The Society has grown and evolved thanks, in part, to the volunteers who have given their personal time and energy to promote the safety and quality of gloveboxes/isolators. This is accomplished by disseminating information through our conferences and AGS Standards/ Guidelines which help direct the design and fabrication of glovebox/ isolator systems. It is truly a pleasure to be a part of the AGS, and after 22 years in this industry, I look forward to the years ahead and where the new technology will take our Society.

One of my main goals this year is to reach out to other industries and communities. We need to promote AGS to the younger generation and look to unite our Society with similar industries, namely the hot cell industry. Hot cells and gloveboxes are very unique, and typically you don't see hot cells in any facility without an accompanying glovebox nearby. This year we were invited to the Hot Lab conference in Leuven, Belgium. The AGS presented our mission at this conference to establish a relationship between the hot cell industry and the AGS. An invitation was extended and we hope to see Hot Lab attendees at future AGS Conferences. We are planning an outreach near one of the DOE sites (Oak Ridge, Los Alamos, Idaho Falls, or Savannah River), to connect with operators, users, and students that might not have the chance to attend our Conference. We hope this will promote interest and participation in the AGS.

This summer, our annual Conference will be held in New Orleans! I am so excited to visit this amazing city and take in the music, the food, the art, and the ambience that it has to offer. Our theme this year for the focused training will involve gloves and the challenges gloves bring throughout the glovebox industry. Our technical presentations will include pharma projects, hot cell considerations, inert gloveboxes, and nuclear glovebox & equipment integration projects.

Thirty years as a society is an amazing accomplishment. The fact that our Guidelines and Standards of Practice, written by our Standards Development Committee, are recognized worldwide is a tribute to the historical knowledge, experience, and commitment that the members of the AGS bring to the glovebox industry. It is an honor to be your President and I look forward to what the next thirty years brings to our Society.

Regards,
Justin Dexter
AGS President 2015-2016

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Application of Linear Synchronous Motors for Material Transfer in Gloveboxes

Nicholas Vrettos, Merrick & Company
Steven Kereakoglow, Merrick & Company
Justin Dexter, M.Braun, Inc.

Merrick & Company, in cooperation with MagneMotion, have developed a linear synchronous motor driven material transfer system for gloveboxes (Figure 1). The MagneMotion QuickStick HT system has been adapted transport loads up to 500 lbs. Many issues including turning, glovebox wear, and fabrication have been addressed. Existing challenges are also discussed including fabrication challenges and outstanding software development needs.

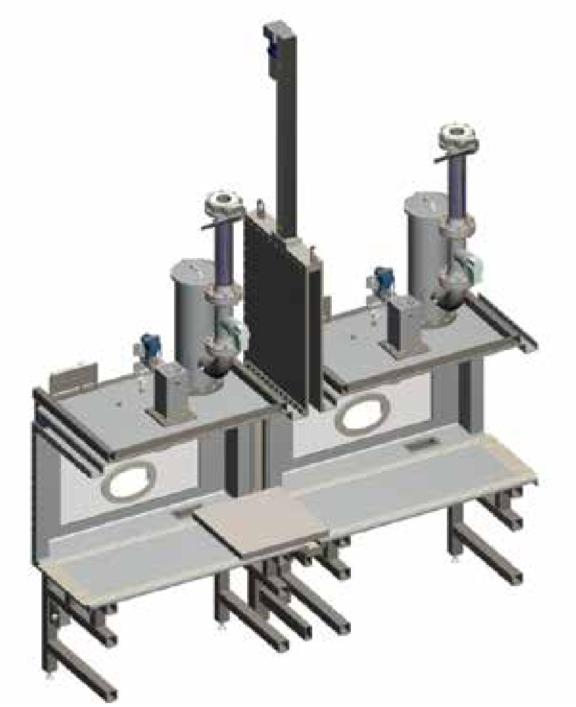

Figure 1: MagneMotion system

Background

The movement of materials through glovebox lines is an issue which must be addressed in nearly every glovebox train. In some cases the materials to be moved are light enough that manipulation by hand is practical. However, often times the materials are of significant mass and involve moves outside of safe ergonomic limits. In these situations mechanical assist devices are needed to prevent operator injury and to facilitate efficient operations.

Existing techniques for material transfer are the use of sliding trays, linear slides, and manual carts. While each of these techniques has their place, they each also have their limitations. Sliding trays are cost effective and robust, however, they require operators to perform actions which are either out of safe ergonomic reach limits or exceed safe loads. In addition, they introduce wear issues on the glovebox floor. Linear slides are able to reduce the forces the operators are required to apply by reducing friction loads or through the use of motors, or both. However, they introduce 'crap traps' and introduce material accountability issues. When motors are introduced they provide maintenance and heat rejection issues if mounted internally to the glovebox or they introduce penetrations which are undesirable design features. Furthermore, they reduce the useable workspace on the glovebox floor. Manual carts are capable of reducing operator strain, but as payloads increase the force required to stop a cart in motion increases and increases the potential for operator injury.

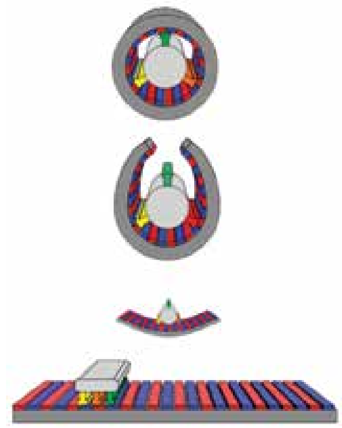

Figure 2: Illustration of 'unrolling' a motor rotor & stator

Merrick and Company has developed a linear synchronous motor (LSM) system which addresses all of these concerns. The system is based around the MagneMotion HT QuickStick LSM system. LSMs are motors that have the rotor and stator 'unrolled' into a linear configuration (See Figure 2).

The LSM will have two distinct portions; the fixed and the motive. The fixed portion (motor), often called the primary, contains electromagnets which are electrically powered. They will generate alternating magnetic fields which will interact with the motive part, often called the secondary or magnet array, which is comprised of an array of permanent, rare earth magnets. The most common and recognizable use of LSMs is on mag-lev trains, or 'bullet trains'. While there are significant differences in the operation of a mag-lev train and the LSM material transfer for gloveboxes, the underlying principle is the same.

Variables which are essential to control are the motor-magnet array gap (magnetic gap) and distance between successive motors in the motor train (motor gap). The thrust the system is capable of generating is proportional to the magnetic gap. Also, it is necessary for a minimum length of each array to be interfaced with a motor to keep the motors synchronized with the arrays.

Proof of Principle

Upon selection of the MagneMotion system as the material transfer system, mock-up testing was performed to prove the principle. Of primary concern was the ability of the MagneMotion system to operate appropriately through 300 series stainless steel. A mock-up was built which simulated glovebox 7 gauge stainless steel floors, door gaps, and intersection. The preliminary design used a 'double-bogey' cart design which used two carts connected by a hinged joint (Figure 3 & Figure 4).

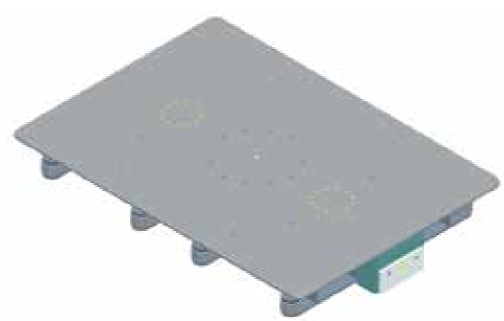

Figure 3: Double bogey cart

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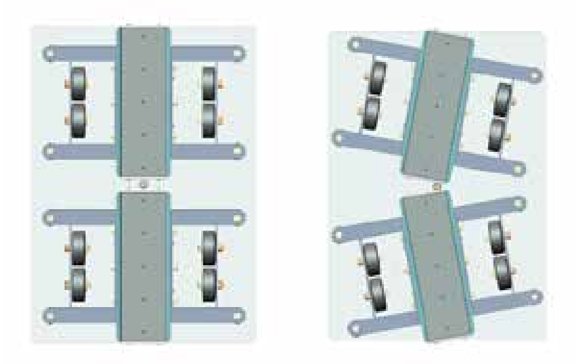

Figure 4: Double bogey cart, bottom view

Rails which protruded up from the floor were used to guide the cart through broad sweeping turns to effect direction changes. The mock-up of this configuration can be seen in Figure 5.

Figure 5: Mock-up testing

The testing proved that the system was capable of moving a load exceeding 1800 lbs through 7 gauge stainless steel, navigating turns, crossing door gaps, and was not overly sensitive to variations in floor flatness.

System Design

After completion of the testing some modifications to the system design were implemented. In the production system designed by Merrick, the magnet arrays are mounted to the underside of a cart in a cross configuration. In addition, the cart uses ball casters to allow omni-directional travel (Figure 6).

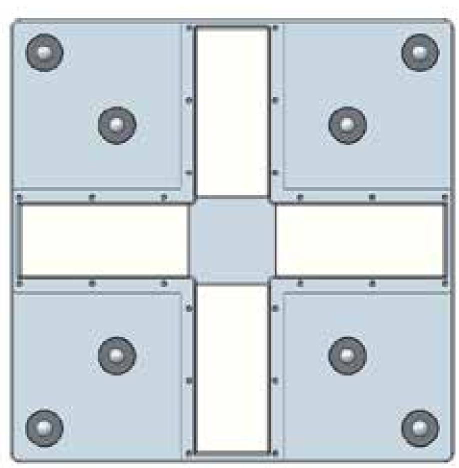

Figure 6: Magnet array and ball caster configuration

These changes to the cart design allow for a much more versatile system without excessive equipment within the glovebox. The only equipment mounted to the glovebox floor are low profile tracks which are easily cleaned and do not interfere with operations (Figure 7).

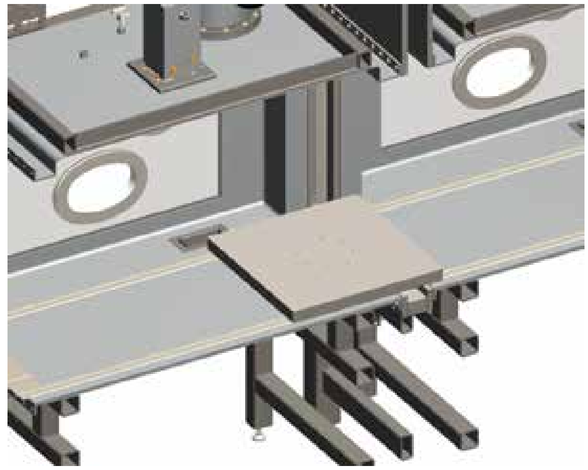

Figure 7: Production cart design

The cross configuration of magnet arrays is actually two sets of arrays offset by 90 degrees. When the cart needs to change direction, the cart body will not rotate, rather, the cart will drive over a corresponding cross configuration of motors beneath the glovebox where the cart will then couple with the intersecting train of motors (Figure 8).

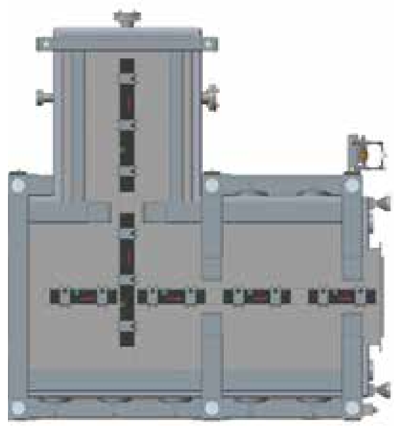

Figure 8: Motor intersection

It is expected that the system will support loads exceeding 500 lbs. In order to maintain stiffness while not making the cart excessively heavy, the body of the cart was machined out to reduce weight. To support maintainability the cart was designed to allow top-side maintenance to the extent practical. This was achieved by mounting the ball casters through the top side of the cart which allows operators to easily replace casters which may have failed (Figure 9).

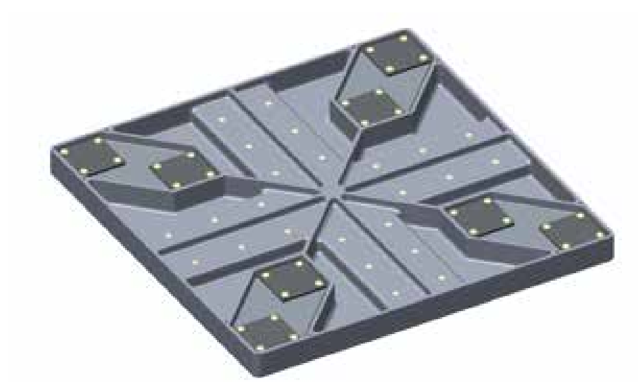

Figure 9: Cart design with interface plate removed

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The cart is also supplied with an interface plate which serves multiple purposes. The first of which is that it covers the internals of the cart to eliminate crevices to facilitate decontamination and material accountability. Secondly, the interface plate provides a feature which is easily adaptable support mounting different payloads (Figure 10).

Figure 10: Cart design with interface plate

It was determined through testing that it is necessary to have dual tracks to control the cart path. Without tracks, the MagneMotion system will tend to drift and lose synchronization. The potential to use a single track was investigated but it was determined that the flatness required of the glovebox floors to ensure the cart casters were adequately captured by the tracks were excessively tight and causes manufacturing costs to become prohibitive.

The doors between gloveboxes introduced obstacles which needed to be overcome. The method used to traverse the gap is the cross ball caster configuration (See Figure 6). The cross configuration allows one pair of casters to cross the door gap while the cart is supported by the other pair. (see figure 11)

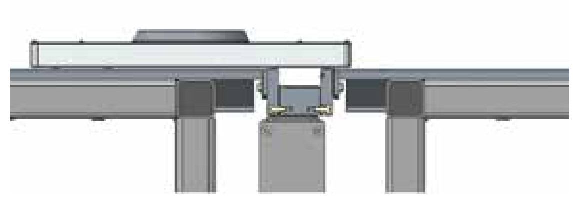

Figure 11: Door gap

Figure 12: Door gap pick-up plate

As the interior set of ball casters is only needed at the door intersections, the tracks for those casters are only provided at the door gaps through the use of pick-up plates located at doors (Figure 12).

The production system is currently in fabrication and is expected to be ready for full scale testing next year. ❖

Microwave Furnace Technology in Glovebox Applications

By: Greg Wunderlich, AECOM

Microware Furnaces are cool (pun intended). They just are…

The purpose of this article is to provide an overview of Microwave Furnace Technology for melting metals as it relates to gloveboxes and the glovebox industry. This article will be presented in two parts. This first article will discuss common furnaces used in the glovebox industries, provide an overview of microwaves, and discuss the common components of a home microwave oven. The next article to be presented in the following edition of Enclosure Magazine will discuss how to melt metals in a microwave oven, the integration of microwave ovens with gloveboxes, and their advantages/disadvantages.

Furnaces in general, are used throughout the nuclear industry and are often integrated into glovebox lines for processing various materials. Microwave furnaces can offer several advantages as compared to other furnace technologies. Thus it is important to understand how they work, the primary components used in a microwave furnace, their advantages and disadvantages and how they can be integrated with gloveboxes. Obviously it is not possible to explain all aspects of microwave furnace technology in a couple of articles let alone a full text book, but an attempt will be made to provide the basics. The author encourages the reader to study microwave technology and furnaces themselves, and to engage experts in the field if pursuing the incorporation of microwave furnaces in their processes.

Furnace Processes

Furnace operations vary immensely from heat treatment to sintering, calcination, stabilization, melting of materials, and to other various thermal processes. This article will focus on the melting of metals using microwave furnaces. Reasons for melting metals include but are not limited to: casting of net shapes, metal alloying, separation of materials, precursor to size reduction, waste consolidation, and sanitization (i.e. changing a shape to another unrecognizable shape). Microwave furnaces are not traditionally thought of for melting metals, and many of us know what happens when we leave a metal fork or foil in the home microwave. The results can be spectacular and startling as sparks erupt. There are hundreds of YouTube videos showing the various cacophonies of dramatic events when items are placed in a microwave from compact discs (CDs), forks, spoons, eggs, and one of my favorites the split grape (you will need to look this one up). However, microwave furnaces can safely be used to achieve temperatures high enough to melt many of the common metals.

Common Furnaces

Resistance furnaces, utilizing radiant heater panels or exposed heating elements, and induction furnaces, utilizing induction coils, are typically used to melt metals in glovebox applications. The primary heating mechanism for a resistance furnace is via thermal radiation from heating elements/panels utilizing Iron-Chrome-Aluminum (Fe-Cr-Al) alloy or Molybdenum Disilicide, to the workpiece, crucible, fixtures, insulation, and chamber. Everything is heated in a resistance furnace.

In an induction furnace, a high frequency electrical current passes through a copper coil (primary coil), and in turn 'induces' a high frequency current in the secondary coil (i.e. work piece and subsector such as crucible or heating plate) which generates heat due to the electrical resistance to the induced current. During this process the copper tubing is heated due to its internal electrical resistance and radiation from the work piece or susceptor and therefore needs to be cooled. Water is commonly used in induction furnaces as the cooling media, which is generally undesirable in the nuclear industry, although air cooling is possible at lower temperatures. There are other types of furnaces such as arc melting but will not be discussed here.

This leads to alternate furnace technologies, such microwave furnaces that are equally as capable in gloveboxes environments.

Microwaves

Microwaves are electromagnetic waves carrying energy and momentum that can travel through empty space at the speed of light. The electromagnetic spectrum is shown in Figure 1 (Reference 1).

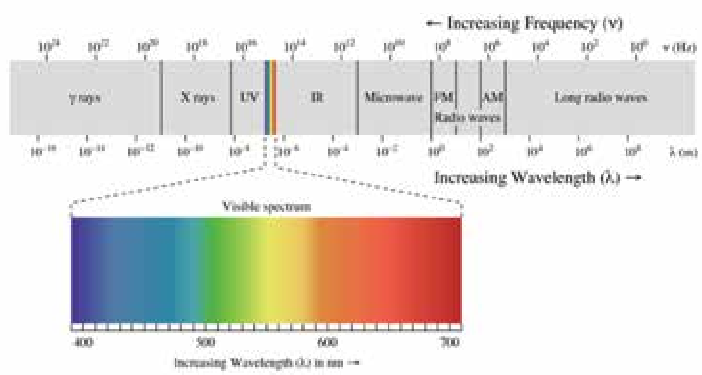

Figure 1 – Electomagnetic Spectrum (Reference1).

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The microwave spectrum is generally 300 MHz to 300 GHz (Reference 2) which corresponds to a wavelength of 1-mm to 1-m. It is noted briefly that it is possible to find different definitions for the microwave spectrum such as 1 GHz to 100 GHz, however it is not a concern for this article as we will be discussing one primary frequency that is in both ranges. Wavelength is calculated using the relationship $c=f\lambda$, between the frequency (f), wavelength (λ), and the speed of light (c). Home microwave ovens operate at 2.45 GHz. For a microwave oven operating at 2.45 GHz the wavelength is calculated to be 4.82 inches (122-mm) which is about the length of a good size potato (Figure 2).

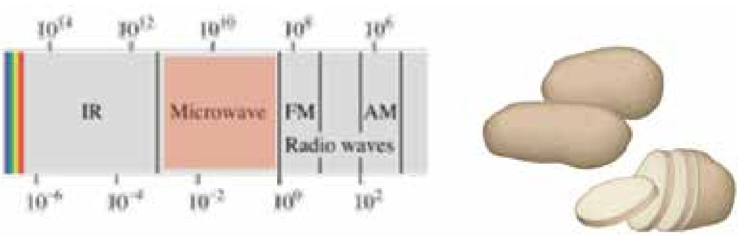


Figure 2 – Wavelength at 2.45 GHz.

Microwave Interactions

Microwaves interact with various materials differently depending on several factors. In simplistic terms, there are three general ways in which microwaves interact or don't interact with materials: (1) the material is reflective (i.e. it will reflect the microwaves), (2) the material is transparent to the microwaves (i.e. there is no or little interaction with the microwaves), and (3) the material will absorb the microwave and heating will take place. In reality all three interactions can be occurring at the same time to a degree and the mechanisms can be more complex. Figure 3 shows these various interactions (modified from Reference 3).

Many are already familiar with these forms of interaction using their home microwave ovens. For example, many of the microwavable safe containers/dishes are primarily transparent to microwaves such as plastic ware and ceramics. These items are generally being heated up by the food that is heating up in the microwave. Other items are reflective in a microwave such as large metal surfaces (i.e. no small features or thin edges). The inside chamber of the microwave is a good example of a reflective surface. However, if for example a metal fork is left in a microwave oven, the microwaves will cause a charge to build up around the tines which causes a dielectric breakdown of the air resulting in arcing. Food and other items heat up in a microwave oven because the microwaves are interacting (absorbing) with these materials. In essence, a home microwave is set at a frequency of 2.45 GHz which works well for interacting with food and water. Microwaves can also interact with powder metal, metals above a certain temperature, and silicon carbide for example. Microwave interaction is related to a couple of different material properties: the dielectric constant and dielectric loss factor which is the capacity of a substance to absorb microwave energy and convert it to heat.

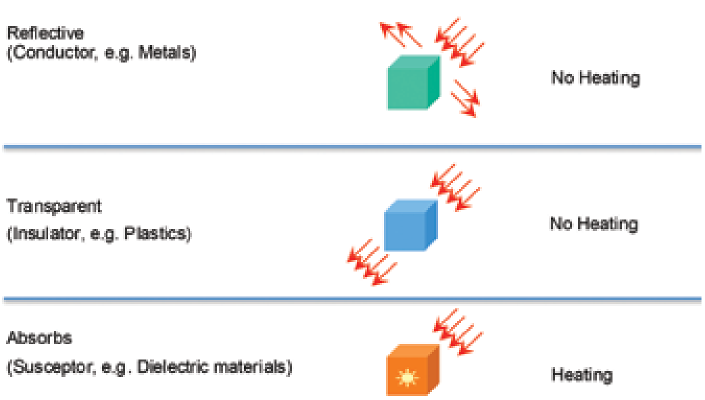


Figure 3

Some molecules (e.g. water) are naturally polarized. This means that the molecules have positive and negative charged ends which are separated by a finite distance. Polar dielectric materials will 'couple' with the microwaves and act as susceptors in a microwave field. The molecules will try to orient themselves within a rapidly changing electric field caused by the microwaves, thus causing molecular vibration. The molecules in essence will rub against each other causing friction, and the release of heat (see Figure 4).

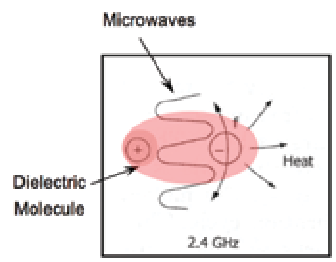
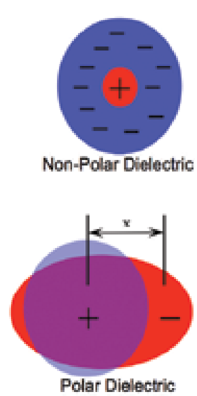


Figure 4 – Microwave Interaction and Heat Release (From Ref. 4)

Non-polar dielectric materials have a center of gravity where the positive and negative charges coincide. The dielectric constant (i.e. permittivity) is the extent to which a dielectric undergoes polarization or orientation on the application of an electric field (Reference 2). Figure 5 shows the dielectric constant for different materials. As can be seen, various foods have a relatively high dielectric constant whereas polyethylene (a plastic) and pyrex ware (i.e. glass) have lower values. Figure 5 shows the dielectric loss factor for various materials. Water has a high dielectric loss



Material	Specific Heat kJ/kg°C	Dielectric Constant Permittivity, ε_r
Carrots	3.80	65.0
Cabbage	3.93	62.0
Peas	3.30	64.0
Potatoes	3.35	38.0
Tomatoes	3.97	61.0
Onion	-	63.0
Spinach	3.40	62.0
Ham	2.51	45.0
Fish	3.35	-
Beef	-	40.0
Bread dough	-	20.0
Polyethylene	2.30	2.3
Pyrex ware	0.84	4.0
Silicon carbide	-	30.0
Water	4.18	80.3

Figure 4b -

Material	tan δ (3GHz, T=25°C)
Quartz	0.6
Borosilicate	10.6
PTFE, PFA	1.5
PE	3.1
PVC	55
Ceramic	5.5
Water (25 °C)	1570
Water (95 °C)	470

Figure 5 – Dielectric Constant (From Reference 4)

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factor whereas a plastic (e.g. polyethylene) has a low dielectric loss factor. It can see from this table why water heats up well in a microwave whereas the Pyrex bowl it is put in does not heat up by interaction of the microwaves.

So, this raises a question: "How can metals be melted in a microwave furnace in a controlled process if they are largely reflective and do not heat-up directly by microwaves?" This will be explained in the next article, but first it is important to understand the major components of a microwave furnace. A good way to explore this is to review a home microwave oven.

Components of a Microwave Oven

Figure 7 shows the main components of a microwave oven: (1) applicator, (2) magnetron, (3) waveguide, (4) control circuit, (5) container, (6) the item being heated, (7) circulating fan, and (8) air exhaust.

The inside walls of the microwave oven where items are heated is called the applicator. The applicator consists of relatively large metal surfaces which reflect the microwaves inside the

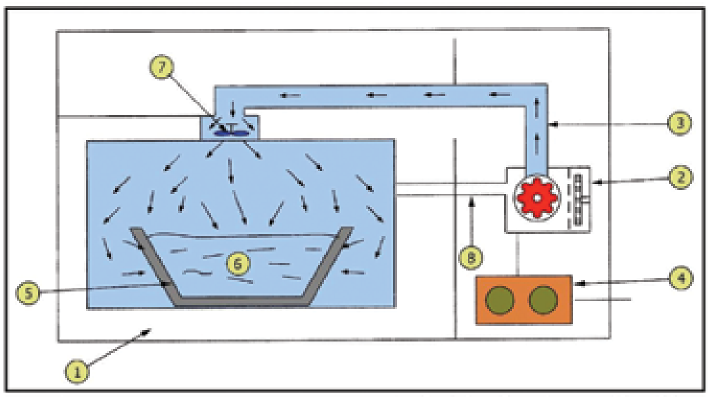

Figure 7 – Microwave Oven Components (From Reference 4.)

oven towards the items that are being heated in a microwave.

The magnetron is where the microwaves are generated. The magnetron consists of a metallic lobed circular vacuum tube with a cathode and anode, and a permanent magnet frame (Reference 3). A high voltage is applied to the cathode to emit electrons, the electrons are drawn into a path produced by the applied magnetic field, the electrons resonate in the cavities of the resonators, and the polarity of the electrical field reverses with the desired frequency and produces microwaves (Reference 3). Figure 8 shows a schematic of a magnetron and an actual home microwave magnetron sectioned.

The wave guide is a hollow metal tube that 'guides' the electromagnetic waves (microwaves) to the applicator. The wave guides are typically an aluminum copper alloy. The wave fronts travel down the waveguide by reflecting from the side walls in a zigzag pattern (see Figure 9).

The other components of the microwave such as the container, the item that is to be heated, the circulating air fan, and

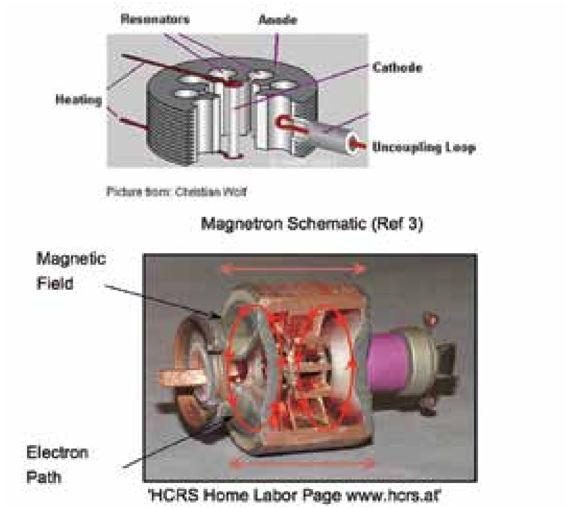

Figure 8 – Magnetron

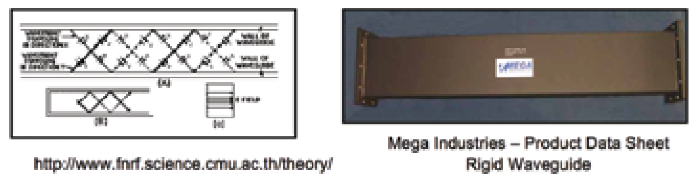

Figure 9 – Wave Guides

circuitry (including a step up transformer) are self-explanatory. There are other features of a home microwave not covered in this article. One feature worth brief mention is the front door of the microwave oven. Microwave ovens have a metal perforated plate normally sandwiched in glass so that the inside of the oven can be seen while the food is heating. The hole size in the perforated plate is much smaller than the wave length of the microwaves and "acts" as a solid plate to the microwaves while visible light is able to pass through the perforations and allow the user to see into the microwave oven.

Again, the question that was raised earlier, "how can metals be melted in a microwave furnace in a controlled process if they are largely reflective and do not heat-up directly by microwaves?" There are two additional key items not present in your home microwave necessary to melt metals. These will be discussed in the next edition of the Enclosure Magazine, along with the integration of microwave furnaces with gloveboxes, and their advantages/disadvantages. Hopefully this article has peaked your interest in microwave technology and microwave furnaces as they are really "cool" (pun will be explained in the next article).

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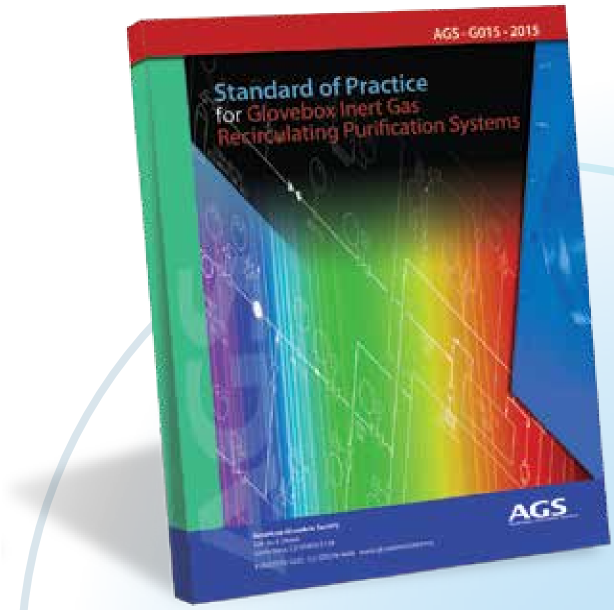

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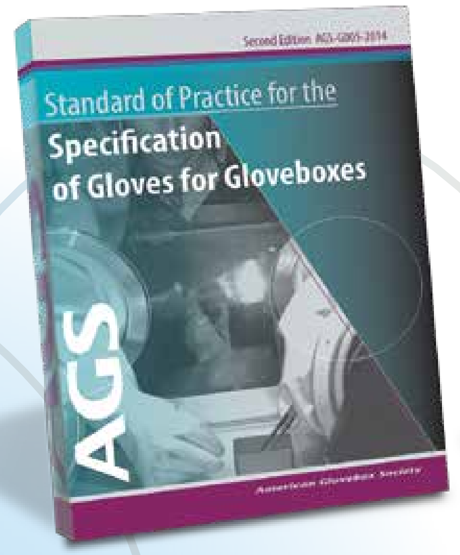

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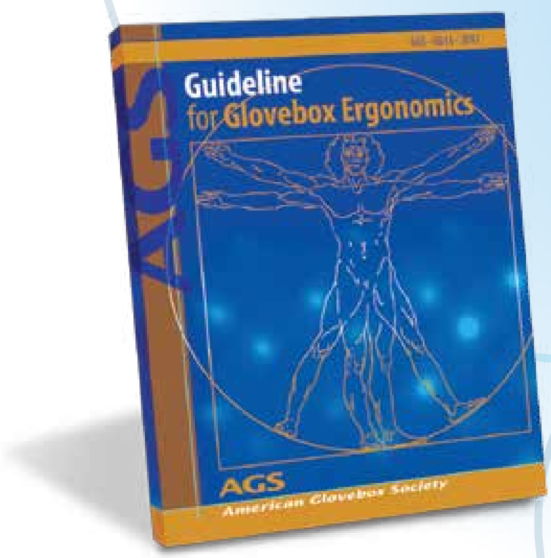

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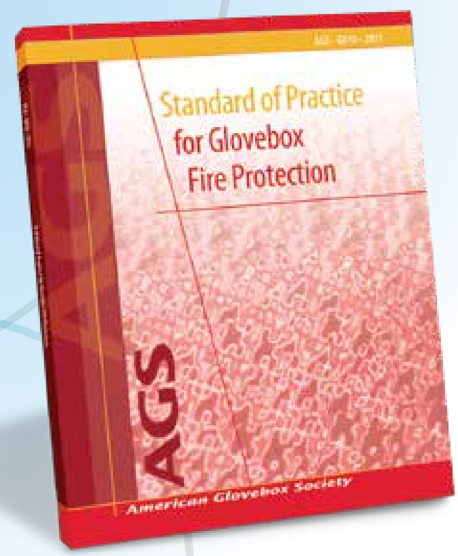

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