Webinar Script

Introduction – Slide 1 (Title)
On behalf of the International Copper Association and all its affiliates and copper centers around the world, I would like to welcome everyone to this Webinar. My name is John Hipchen and I will be one of the presenters today.

This is the International Copper Association's third webinar discussing the industry trend toward smaller diameter copper tubes, known as MicroGroove tubes. Past webinars have focused heavily on MicroGroove technology, delving into details about the reduction of boundary layers and the heat transfer advantages that come from the increased surface area of small diameter MicroGroove tubes. We have covered in detail case studies that demonstrated the performance and cost-reducing benefits of MicroGroove tubes due to lower material use, lower refrigerant charge and more compact air conditioning and refrigeration units. Past webinars are archived on the MicroGroove.net website along with additional information such as technical papers and resources related to the use of MicroGroove tubes. And today's webinar will also be archived at MicroGroove.net.

In today's webinar, we are going to take a few minutes to review the basic technology behind MicroGroove tubes and then we are going to focus on manufacturing. We will discuss production practices for air conditioning and refrigeration coils using conventional tube sizes and then we will talk about building coils with small diameter MicroGroove tubes. We will indentify the challenges involved in manufacturing coils with smaller diameter tubes. And we will learn about the manufacturing solutions that are being successfully used to overcome those challenges. We are most fortunate today to have the assistance of Burr Oak Tool Incorporated.

Slide 2 – Burr Oak Tool Introduction
Often referred to across the globe simply as "Oak", Burr Oak Tool is a leading manufacturer of coil production equipment. And if you have ever been inside a coil manufacturing plant, chances are that you have seen machinery built by Burr Oak Tool. When it comes to building ACR coils with round tubes, Burr Oak builds machinery that covers every aspect of the production process…and that includes fin lines and fin dies, tube benders and tube cut-off machines, tube expanders and coil form machines that can bend finished coils to very exact dimensions.

We will discuss the coil production process and all of the machinery in a few minutes. But first, let's review the basic technology behind the use of MicroGroove tubes and let's talk about why the industry is moving toward the use of smaller diameter copper tubes. And I apologize if you are already familiar with this technology, but for those who are not, this will show rather quickly why the industry is moving in this direction.

Slide 3 – Photo of Coils
To make sure that we are all on the same page, the type of coils we will be talking about today are round copper tube, flat fin coils.

Slide 4 – Photo of ACR Units
They are used in a number of applications that cover residential, commercial and industrial settings. These coils can be condensers, evaporators, water heating coils and a number of other heat exchanger uses. Round tube, plate fin coils have been around for over 100 years and there are good reasons why they are still in use today.

What we will see in the next few slides is that these reliable, older designs are evolving into newer, more efficient designs that use smaller diameter, internally enhanced copper tubes that we call MicroGroove tubes.

Slide 5 – Increased Heat Transfer

MicroGroove tubes produce two phenomena that are largely responsible for all of the advantages and benefits that are pushing the evolution of copper tube-plate fin coils. Because of reduced boundary layers and increased surface area, MicroGroove tubes result in a dramatic heat transfer advantage. And this allows the engineers that design ACR coils to do a number of things that can not be done with larger diameter tubes or flat tubes. The name "MicroGroove" refers directly to both of these phenomena – "Micro" referring to the smaller diameter tubes and the increased surface area that results from the smaller diameters and "Groove" refers to the internal enhancements inside the tube that reduce boundary layers. So the name "MicroGroove" means internally enhanced, smaller diameter tubes. Today, MicroGroove tubes are commercially available in diameters down to 5mm but there is work being done on yet smaller diameters. Future discussions about MicroGroove tubes could very well involve diameters smaller than 5mm.

Slide 6 – Development of Boundary Layers

Whenever fluid moves through a tube, the fluid closest to the tube wall behaves differently than the fluid in the center of the tube. The fluid next to the tube wall sets up a boundary layer where heat transfer becomes more difficult. And this applies to the hydraulic motion of fluid, as well as the way heat moves from the center of the tube to the tube wall. Fluid closest to the tube wall tends to move slower than the fluid in the center. Even in turbulent flow, a laminar sub-layer forms and heat moves slower through these boundary layers than it does in the faster-moving fluid toward the center of the tube. These boundary layers act as an insulator and they interfere with the heat transfer that we want. Here we can see the boundary layer in a smooth tube develop and it does not dissipate or go away.

Slide 7 – Reduction of Boundary Layers

MicroGroove tubes have internal enhancements and grooves that reduce the formation of boundary layers. You can see that the boundary layer begins to develop, but it breaks down as it moves over the grooves. The additional mixing of the refrigerant that occurs inside the tube because of these grooves increases the amount of refrigerant that comes in contact with the tube wall. The positive effect on heat transfer from these internal enhancements has been known for a long time and applied commercially for over 20 years. And, when combined with small diameter tubes, we have even more advantages that we will look closer at.

Slide 8 – MicroGroove Features

The enhancements inside of MicroGroove tubes are proprietary patterns that tube manufacturers put on the inside tube wall. The exact configuration of the internal grooves and patterns is based on a long history of technical development and design, and is backed up by both experimental and field performance data. And the data clearly shows significant advantages to MicroGroove tubes. Now let's look at what happens when we combine the increased efficiency of internal enhancements with smaller tube diameters

Slide 9 – Reduced Tube Diameters = Increased Heat Transfer

When we compare tubes of different diameters, one of the first things we notice is that it will take several smaller diameter tubes to equal the surface area of a larger diameter tube. But this is not a disadvantage. We actually have important benefits here, a big one being an increase in the surface area to volume ratio and that equates to more heat transfer. And, with this increase in heat transfer, we don't need to match the volume or surface area of the larger tube to get the same amount of cooling. Using smaller diameter tubes, we can actually match the cooling of the larger tubes with less volume and that means less refrigerant. Another benefit is that in a smaller diameter tube, we can hold the same pressure as the larger diameter tube but we can do it with thinner tube walls. And there are case studies that clearly demonstrate how important this can be to the overall cost of a system. So, when we reduce tube diameters, we can actually reduce the weight of the materials being used and in turn, reduce costs.

Slide 10 – Increased Heat Transfer with Less Material
And, as we continue to reduce tube diameters, we continue to gain surface area in relation to the amount of refrigerant that we have in the tube. And we can continue to reduce tube wall thicknesses while still meeting the same pressure criteria as the larger tubes. If we happen to be dealing with higher pressures, as many of the newer refrigerants require, we can handle higher pressures in small diameter tubes with thinner tube walls than larger tubes would require. The bottom line, is that we can do a whole lot more with considerably less material.

Slide 11 – Photo of Replacement Coil
This photo represents a real-life example of what we just reviewed. This is taken out of a catalog on the internet and the new design in this picture shows smaller diameter tubes that provide 35% more passes which will result in considerably more heat transfer. But you will notice that the tubes in the new design are arranged in a staggered pattern which will again, improve the efficiency of this coil. And the ability to arrange the tubes in more efficient geometric patterns is yet another advantage of round copper tubes.

We want to turn our attention now to manufacturing but before we do, let's quickly review the benefits of smaller diameter MicroGroove tubes.

Slide 12 – Benefits of MicroGroove Tubes (bullet list)
There are a number of reasons why coil manufacturers are modifying their lines for smaller diameter tubes and this list gives us a quick snapshot. The improved heat transfer technology that we just discussed results in more energy efficient, smaller and lighter coils…bringing about all of these benefits to air conditioning and refrigeration systems. Keep in mind that each of these benefits is not only associated with meeting energy and refrigerant regulations, and regulations do continue to change, but each benefit also means cost reductions. Advantages like less refrigerant and less material are especially important to cost reduction programs and these benefits are often times the driving force behind new designs.

Slide 13 – Coil Manufacturing – John Introduces Ned Haylett from Burr Oak
Let's turn now toward the technology behind manufacturing ACR coils with conventional tubes and with smaller diameter MicroGroove tubes. I'm going to turn the webinar over to Ned Haylett now from Burr Oak Tool Inc.

Slide 13 – Ned Haylett
Good afternoon, ladies and gentlemen. I am Ned Haylett, Vice President of Sales for Burr Oak Tool. With us today is Randy Sible, our research and development manager. We'll be discussing the general manufacturing process of heat exchanger coils from small diameter copper tubing such as 5mm. Burr Oak Tool has been in business since 1944 and building production machinery for the air conditioning and heating market since the mid-1950's. We have an office in the Czech Republic to provide support for our European and Middle East clients, one in India for that specific market, and also one in China. We have sales representatives for Mexico, Brazil, Korea, Japan, and Thailand but all of the manufacturing is performed here in our original factory in Sturgis, Michigan, USA. We have supplied production machinery to air conditioning and heating facilities in more than 70 countries on just about every continent.

John mentioned the industry trend toward round copper tubes with smaller diameters and at Burr Oak, we actually started dealing with this trend years ago when manufacturers started replacing 1/2" tubes with 3/8" in the 1960's…and more recently 3/8" diameters are being replaced with 5/16" and 7mm designs. As we just saw in the previous slides, there are good reasons to reduce tube diameters even further and many of our customers are now turning to us for equipment that can produce redesigned coils with 5mm diameter copper tubes.
So we're going to take the next few minutes to look more closely at coil manufacturing in general, and more specifically at what it takes to manufacture coils with tubes as small as 5mm in diameter.

Slide 14 – Typical Process
Our first order of business will be to provide a quick review of the four basic areas of heat exchanger production. These are fin stamping, tube processing, fin handling and lacing, and, finally, expansion. Once we have finished discussing all 4 of these basic processes, we will have a nearly complete heat exchanger but it won't be quite ready for installation. Your manufacturing process will also include a brazing operation to seal all of the joints and some applications require that the flat coil that has been produced be formed into a particular shape, such as a 'L' or 'U'. For today's discussion, we'll concentrate on these four primary processes.

Slide 15 – Typical Process, Fin Stamping
This slide shows a representative fin line, including an uncoiling system, lubrication method, press, die, suction unit, and stacking mechanism. These are available in various sizes and levels of complexity but, essentially, all lines perform the same function…the production of fins and the placement of these fins into a specific arrangement or stack. This stack is then manually removed and taken to the lacing area.

Various fin stock materials can be used. Primarily the material of choice is aluminum. There are also applications, such as marine environments or anti-microbial characteristics that require the use of a totally copper coil. Mild and stainless steel is sometimes used as fin stock in corrosive atmospheres. The stock comes in various widths, depending on the number of rows of the fin die and the tonnage capacity of the press.

The size of the fin die and press combination is governed by your production requirements. Our present presses have 30 ton, 60 ton, 100 ton, and 160 ton capacities and can support increasingly wider material. The increasing tonnage also reflects an increasing capital equipment price but the real question is the price per hole produced. If high production rates are required, a larger press can manufacture fins more efficiently, providing a lower cost per hole produced.

The suction unit provides the support for the fin before it reaches its correct length and is cut. The stacker mechanism comes in many different styles and collects and maintains these cut fins in a vertical stack in preparation to their removal when the stack is complete.

Slide 16 – Typical Process, Fin Die
The fin line supports the fin die, the actual tooling that determines the configuration of the fin itself. It is a progressive type die and can be either a draw or an extrude design.

Let's discuss these definitions for a minute. A progressive die is one that moves the material in specific increments, performing a unique task at the end of each transition.

Slide 17 – Typical Process, Fin Stamping, Standard Progression
In the fin die, these transitions are usually draws (which gathers material for the collar), the pierce (making the collar hole), the reflare (providing the final collar height), edge trim (finishing the outside

edges of the fin stock), slit (determining the number of rows wide in each fin), feed (providing the movement of the fin stock through the die), and the cutoff (making the correct length of fin).
A draw type die is one that uses a technology of gathering material in a series of steps to provide the collar height. This process allows the easy adjustment of a fairly wide range of collar heights and the use of various fin stock thicknesses.
An extrude type die (also called ‘drawless’) uses a thinning process to form the collar height. This technique is useful when processing fin stock that has a very hard temper and low elasticity characteristics.

There are appropriate applications for either style of die.

Many aluminum fin stocks are also coated with anti-corrosive or hydrophilic material. These can be abrasive to fin dies unless they are properly prepared with appropriate tool steels.

Slide 18 - Typical Process, Fin Stamping, Collars
Another major requirement of the fin die is to provide accurate and consistent collar heights for these fins. These collars actually establish the spacing of one fin to another. This specification is relative to the application for which the coil is being used. For instance, refrigeration applications may require quite tall collars, increasing the spacing between fins while air conditioning applications generally use shorter designs.

Slide 19 - Typical Process, Fin Stamping, Fin Surface Configurations
The surface area between the pattern holes is subject a vast array of designs. Some fin designs are solid with different types of topography, such as sine wave and ‘V’ waffle forms as shown in the upper portion of this slide. Others, as shown in the lower portion, use cuts in the fin surface to either redirect the air flow or to create turbulence to enhance the heat transfer characteristics of the fin. Depending on the shape of the design, these are called “louvers” or “lances” and can be installed in a surface form.

Slide 20 - Typical Process, Tube Processing
In the tube processing portion of this process, we include hairpin benders, straight tube cutoff machines, and return bend machinery.
The hairpin bender provides the long, 180 degree bends for insertion into the heat exchanger coil and is generally comprised of an uncoiling system, feed and cutoff unit, and bending mechanism. Straightening is performed in the feed area and has been, until recently, generally done by a roller system. The cutting of the tubing is done by an oscillating tool and does not produce chips or scrap. Removal of the finished hairpin from the work area is primarily performed manually but, in some cases, conveyor systems take them to a collection area.

The straight tube cutoff machine straightens and feeds tubing to a very precise length and then cuts it with a rotary system, again with no chips or burrs. Straightening of the tube is performed by a 2-plane roller system and the feed performed by a hitch mechanism.

Other machines in the tube processing category include the return bender, sizing and ring machines (for sizing the ends of the return bends and installing the brazing ring) and a cleaning machine. Return bends are shorter than hairpins and designed to determine the refrigerant circuit of the coil. One major difference between the return bend production process and hairpin manufacturing is the cutting operation. Return bends are cut with a saw, creating chips that need to be cleaned from their interior. This cleaning operation is performed with a vibratory system that includes a burnishing media and a degreasing solution and must be done prior to the application of the solder rings.

The uncoiling system for either the hairpin bender, the straight tube cutoff machine or the return bender supports level wound coils of copper in sizes ranging from 100KG to 500KG, depending on various factors.

Slide 21 - Typical Process, Handling and Assembly
Preparation of the fins for the next step of the process includes removing precision stacks of fins from the fin line and transporting them to the lacing area. Stacks of fins are shown in the left hand picture in this slide. The number of fins in each stack is controlled by a counter on the press. The fins are stacked onto long, pointed rods to maintain the alignment between each fin in a stack. The positioning of these stacking rods to the fin being produced by the die is extremely important and is shown in the right hand picture. Removal of the fins is still generally performed manually, however, there are stacker designs that can make this job easier. For instance, an elevator system can be used to lift finished stacks to a height that facilitates their removal by factory personnel. This is important because the completed stacks can be heavy and the fins themselves are quite fragile and minimizing the handling will help eliminate deformed and unusable fins at the top and bottom of the stack. Damaged fins also interfere with the manual lacing of the tubes into the stacks making it a very time consuming and tedious operation. Burr Oak is presently engaged in some research and development programs to study how to completely automate both the removal of the stacks and the lacing of the tubes.

The actual lacing process varies from client to client, depending on sizes of the coils being produced and relative locations of the fin line and hairpin benders. The lacing tables are usually produced locally and their design is very dependent on the internal manufacturing process. The proper number of fins is placed on a smooth, flat table, usually with one raised edge for alignment. The collars are usually oriented so they are directed upwards in the final assembly. The operator performing the lacing process then places the tube sheet for the bottom of the coil into position. For clarification, a tube sheet or end plate is a heavier plate located at the top and bottom of the coil to serve as a support or mounting bracket for the heat exchanger coil in the final assembly. The lacing person then begins to insert hairpins into the coil in a predetermined sequence. Due to the orientation of the fins, the hairpin enters the bottom of the collar first.

Slide 22 - Typical Process, Handling and Assembly, Tube Expansion
After the lacing is complete and the top tube sheet (or end plate) has been added, the heat exchanger coil is ready for the expansion portion of the process. At this point, the fins and tubes are very loosely assembled and, to create a good, strong mechanical fit between the tube, fins, and tube sheets, an expander bullet or ball is pushed down the length of the tube.

Slide 23 - Typical Process, Handling and Assembly, Tube Expansion, Bullet & Bell
This bullet and its relation to the tube and fins are shown in the left side of this slide. The expander also accurately establishes the length between tube sheets and properly forms a cup (or bell) at the open ends of the tubes to allow the placement and brazing of the return bend. This bell design and placement is important because the relation between the bell and the return bend placed into it determines the quality of the final brazed joint. Excessive variation can result in leaks.

Now that we have introduced the various machines that are used in the manufacturing process of a heat exchanger, let’s discuss points concerning the introduction of small diameter copper tubing. The techniques are essentially the same, making this integration more of a transition rather than a completely new technology.

Slide 24 – 5mm Solutions, Fin Press & Die
Returning to the beginning of the 4 basic areas of heat exchanger coil production, let’s talk about the process of transiting to smaller diameter tubing. We’ll begin, once again, with the fin line and die.

Studying the opportunity to use smaller diameter tubing will allow your coil design group to optimize the design of the entire heat exchanger coil for higher and more efficient performance. Government regulation and more aggressive competition are a constant inducement to consider new fin configurations, such as a smaller pattern and new fin surface enhancements. These material cost savings should be evaluated carefully in your discussions concerning new coil designs.
As mentioned earlier, because heat transfer engineers are always under pressure to maximize the overall design of the heat exchangers, reducing the diameter of the tubing is often accompanied by other fin specification changes. If these modifications include making the pattern more dense and changing the enhancement between the holes, it will require a new fin die and, depending on the tonnage or the options, may also involve purchasing a complete new and larger fin line. If a smaller pattern is incorporated, you may be able to increase the production properties of an existing system by installing a die with more rows.

The coil design engineer will need to account for possible collar height limitations due to the smaller diameter and more dense pattern design because there is simply less material for the forming process. This can be solved through die design, material thickness and temper, and quality and quantity of lubricant.

Slide 25 – 5mm Solutions, Fin Stamping, Suction Unit
At the suction unit, more accuracy for the location of the fins and the positive placement of them onto the stacker rods will be required because the pattern holes in the fins are smaller and the small stacker rods are more subject to vibration. For instance, the suction unit may need to be retrofitted or designed with some mechanism that actually pushes the fins away from the surface of the suction sheet and onto the points of the stacker rods.

Slide 26 - 5mm Solutions, Fin Stamping, Stacking Unit
In conjunction with the suction unit, the design of the stacker and its tooling should facilitate efficient, uninterrupted production and minimize handling damage. The base of the stacker must be designed to isolate the vibration generated by the press from the stacker rods and yet it must be rigid enough to support large and relatively dense completed stacks of fins. Both of these criteria help maintain the proper alignment between the incoming fin and the stacker rod.

To further enhance their alignment and to facilitate movement of the fin down the rod to the top of the stack, a specially designed tip should be provided on the stacker rod.

Slide 27 - 5mm Solutions, Tube Processing, Hairpin Bender
Let's now switch again from fin production to tube processing, especially as it pertains to the hairpin bender. Depending on the condition of the machine and the age of its controls, one may be able to retrofit an existing hairpin bender for 5mm copper hairpin production. This should be determined on a case-by-case basis because there are many factors to be considered, possibly even requiring an inspection by Burr Oak to determine if it can be considered for conversion.

When working with any small diameter tubing, tooling will need to be maintained to a higher degree of accuracy. The small mandrels and mandrel rods, for instance, are much more fragile and care will need to be taken to insure their alignment and quality.

The small diameter tube will be more susceptible to handling damage, both as the raw state and as finished hairpins. This can usually be alleviated by proper operator training and the use of support fixtures. For example, an overhead uncoiling system allows the use of larger coils of tubing, minimizing handling damage of the coil stock, longer uninterrupted production times and a higher percentage of up-time for the machine.

Slide 28 - 5mm Solutions, Tube Processing, Straight Tube Cutoff
The straight tube cutoff machine usually requires little in the way of retrofitting for the introduction of 5mm tubing, however, the cycle time of the machine may need to be slowed slightly to help prevent deflection of the tube during the feeding portion of the process. New machines should be equipped with more sophisticated controls and an electrically driven servomotor feed that can better monitor acceleration and deceleration during the feed process to minimize this deflection. The servomotor that provides the power to operate the feed also allows exact positioning of the tooling for highly accurate and repeatable tube lengths and quick and easy set-ups for length changes.

Now let's look, for a minute, to how the machines at Burr Oak Tool incorporate new designs, options, and techniques to provide for the successful and efficient introduction of 5mm microgroove copper tubing into your process. These were developed from our previous experience of helping the industry move from 1/2" tooling to 3/8" diameter in the early 1960's and from 3/8" diameter to 5/16" and 7mm designs in the 1980's and 1990's. While each evolution introduces its own variant of problems, the result has been a more efficient and accurate process, providing a higher quality heat exchanger. More compact coil designs also allow more control of raw material costs.

Slide 29 - 5mm Solutions, Tube Processing, New Electric Hairpin Bender
There are many ways that machinery builders can modify or prepare new machines for the processing of 5mm copper tubes. Here is a picture of a hairpin bender that is specially designed for small diameter processing. It has a smaller footprint, higher production rates, and lower set-up times than previous models. Another major innovation in new hairpin benders is a stretch straightening system to insure the legs of the hairpin are the best possible to enhance the lacing process. This replaces the roller straightening method found on previous benders and initial reports indicate hairpin leg length control is markedly improved.

Slide 30 - 5mm Solutions, Tube Processing, New Straight Tube Cutoff Machine
The straight tube cutoff machine has been redesigned to incorporate an electrical servomotor powered belt feed system and new controls to provide better monitoring of the acceleration and deceleration rates and to maximize its production rate. Without these new controls, small diameter and thin wall copper tubing can deflect under the strain of the feed process, resulting in tubes that are not straight or, in extreme cases, simply buckle, causing scrap and down-time. Set-up times are greatly reduced because a series of lengths can now be programmed through the operator interface and the machine can perform these changes unattended.

Slide 31 - 5mm Solutions, Handling & Assembly, New Fin Harvesting System
The most common problem with stackers is the fin handling damage that takes place when the lacing personnel manually remove the stack of fins from the stacker, resulting in deformed fins at both the top and bottom of the stack. These are then removed and discarded. In answer to that and other stacking issues, Burr Oak Tool has designed and built a prototype fin harvesting system that provides a number of advantages over conventional fin stackers. A few of these points are reduced fin handling damage, continuous press operation (no waiting for the stacker to rotate or shift when the stack is complete), an uninterrupted supply of fins, a more ergonomic stack position, and it could even support an automatic tube lacing system. Due to certain proprietary designs, applications for this system should be discussed with a Burr Oak representative.

Slide 32 - 5mm Solutions, Tube Processing, 5mm Expander
The vertical expander design has been upgraded to include specific options for the production of heat exchanger coils with 5mm or 7mm tubes. These options become especially important as the length of the coil (the between tube sheet dimension) gets longer. These longer coils are more subject to misalignment and collapse during the expansion process unless proper steps are observed.

One option is a tube alignment device to mechanically guide the bullets (or expanding balls) into the open ends of the hairpins. This helps prevent damage to the ends of the tubes, such as nicks and splits. It also helps maintain the position of the tubes for the belling process, thus ensuring higher quality brazing joints.

We have improved enclosure technologies to better maintain straightness of the coil during the expansion process. Controlled movement of front and rear enclosure plates allow them to start the expansion cycle closer to the top of the coil helping to maintain alignment and straightness.

Slide 33 - 5mm Solutions, Expansion
Note the top of the expander in the picture where you can see a programmable expander rod selection device and a floating rod holder system to allow the production of 1 + 1 heat exchanger coils that are used in condensers and formed in 'L' or 'U' shapes.

Burr Oak is also investigating and testing various alternative, non-mechanical methods to help address the inherent limitation of compressive expansion.

Slide 34 - 5mm Solutions, Expansion (continued) & Hand-off to John Hipchen
As a quick addition to our presentation, we show our all-electric coil form machine, designed to bend condenser coils into 'L', 'U', or box shapes without damage to the inside radius. This allows even heat transfer distribution over the entire face area of the coil. The machine in the picture is completely electric and maintains extremely well controlled positioning for highly accurate and repeatable bending. This allows easy assembly into the air conditioning unit.

Thank you for your attention and now I am turning the program back to John Hipchen

Stay on Slide 34 – 5mm Solutions, Expansion
At this time I would like to thank Ned Haylett and Randy Sible, and the entire team at Burr Oak Tool. There is little argument that Burr Oak Tool is a world-renowned authority on coil production equipment and they have been setting the standard in this area for many years. With their new innovations, I am sure they will continue to do so for years to come. It was terrific to have that level of expertise available for this webinar and the ICA truly appreciates their help. Ned and Randy will stay on the line to help answer questions in a few minutes.

I'd like to say at this point, that whenever we engage in a discussion about production machinery, it is important to remember that the conditions and priorities can be very different from one plant to another. Although the same processes take place at every coil manufacturing plant, the configuration of the equipment and level of automation can vary. And the reasons behind these differences range from how high the production rate is, to how much space is available in a plant, or even particular in-house specifications that emphasize a certain aspect of coil production that is especially important to one company. The bottom line, is that a close partnership with a production machinery builder is a key component to successfully meeting coil production goals. And we have seen how Burr Oak Tool has been able to modify their equipment so that coil manufacturers can successfully implement small diameter MicroGroove tubes. So the equipment solutions for MicroGroove tubes are real, and they are available, and being used more and more every day by the air conditioning and refrigeration industry.

Slide 35 – Coil Design Considerations
Throughout our industry, manufacturers and suppliers of ACR systems are considering options that optimize performance and cost. And when considering a choice between materials such as copper

and aluminum, tube designs such as flat vs round, it is a good idea to consider these important factors:
- Corrosion; both internal and external. Remember that copper has a long history of meeting corrosion requirements. Also remember that some metal oxides are essentially the abrasive material we use in sand paper and this could be detrimental inside an ACR system.
- Pressure drop. Pressure drop, both on the air-side and refrigerant side, is something that can increase in designs with smaller diameter tubes. Heat transfer engineers have been managing pressure drop in newer designs by paying attention to design factors such as fin density, tube geometry and tube circuitry. We looked at this in detail during our last webinar.
- Design flexibility. Engineers have considerably more options with round tubes and this gives them an advantage when designing heat exchangers for new requirements.
- Serviceability. Technicians around the world favor copper tubing when it comes to service work.
- Water-shedding. In evaporator applications, round tubes have definite advantages over flat tubes when it comes to shedding water.
- Refrigerant charge. Coils made with small diameter MicroGroove tubes can save dramatically on refrigerant charge, and there are case studies we can provide that give more details on reducing refrigerant. Manifolds that are usually required for flat tubes have to be filled with refrigerant and this can be costly.

Slide 36 – Benefits of MicroGroove Tubes
Many of us are already familiar with the increasing requirements for energy efficiency and the push to use refrigerants that are less damaging to our atmosphere. The MicroGroove technology we discussed today is allowing manufacturers and distributors to meet these demands. So, in conclusion, let me quickly review these basic benefits related to smaller diameter copper MicroGroove tubes. Microgroove tubes allow for energy efficient designs. They allow manufacturers to use less material and less refrigerant. The coils they produce are proven, durable products with a history of success behind them. Small diameter Microgroove tubes allow engineers the flexibility to design for a wide variety of operating conditions. And this is a manufacturing process that is proven, economical, robust and familiar to the entire industry. And finally, this process is supported by a supply chain that is very well established with manufacturing and distribution centers world-wide.

Slide 37 - Concluding Slide, Game Changer Ad
Before we begin answering questions, I just want to remind everyone once again to visit the MicroGroove.net website where you will find archived webinars, technical information, and questions can be left there also. We will respond to questions that come in through this website. And for equipment-related inquiries, visit burroak.com.

Slide 38 – Thank You
Thank you for your attention and at this point I would like to turn things back to our moderator for the question and answer segment of this webinar.

Slide 39 – (Final Slide) Game Changer Ad (to be shown during Q&A)