Webinar II Script

Introduction - Slide 1
Hello. My name is John Hipchen and I will be presenting this webinar today. 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.

Today, we are going to review the technology behind MicroGroove tubes, we will understand why manufacturers can achieve higher heat transfer with less material by using MicroGroove tubes, and we will compare the data from design studies that were performed by original equipment manufacturers or OEM's. If you attended our first webinar on this subject, you will see a few familiar slides as we review the basics, but we have a lot of new data to share today and that will take up the majority of our time.

In the world of refrigeration and air conditioning, manufacturers are continuously challenged to reduce energy use, but competition forces them to do this in the most cost-efficient way possible. MicroGroove tubes are helping coil manufacturers and OEM's meet the demands of the market and at the same time maximize their cost savings and profit potential.

Slide 2 – MicroGroove.net
Before we continue, I want to mention the microgroove.net website where the latest information about MicroGroove tubes can be found. At microgroove.net, you will find news releases, technical papers, information about the suppliers of MicroGroove tubes – plus information about upcoming events and webinars. In fact, you can find links on the microgroove.net website that will take you to archived webinars that can be viewed on-demand, including the webinar from last week and one from last December. And you might make a note that this webinar will also be available on demand.

Slide 3 – Round Tube / Flat Fin Coils
Today we will be talking about refrigeration and air conditioning coils made with round copper tubes and flat fins.

Slide 4 – Outdoor Commercial Condensing Unit
Later in this presentation, we will take a close look at split-type units that have an outdoor condensing unit and indoor evaporator unit. Split-type systems can found extensively in commercial refrigeration systems with often times rather large condensing units such as this.

Slide 5 – Indoor Commercial Evaporator Unit
The corresponding indoor commercial unit often looks like this. Anyone who has worked with walk-in coolers or freezers has probably seen this type of evaporator unit mounted near the ceiling.

Slide 6 – Central AC Units, US Style
But all of us in North America are used to seeing the typical central air conditioning system that looks like this with an "A" coil evaporator that is mounted in the ventilation system and a U-shaped condenser unit that is mounted outdoors.

Slide 7 – Split-Type Unit
In Europe and Asia, the split-type units look like this and often provides both cooling and heating. Another possibility with these split-type systems are more than one evaporator unit indoors. Later in this presentation, we will look closely at data that was generated to optimize these exact systems.

Slide 8 – New Design, 35% More Passes

Round tube, flat fin coils have been used for a very long time – more than 100 years. But this photo right out of an internet heat exchanger catalog shows exactly the trend that we are going to discuss over then next hour. And that trend is toward smaller diameter copper tubes with special attention paid to the arrangement of the tubes. In this photo, the manufacturer advertises 35% more passes and that is important because it translates to higher heat transfer, higher efficiency, less material is used to make the coil and in many situations it also means less energy is used in the system. Note that in the new coil, the tubes are arranged in a staggered pattern and we will see in this presentation how that can make a significant difference in performance. Let's look at the advantages of MicroGroove tubes and the technology supporting the trend toward their use.

Slide 9 – Increased Heat Transfer

The two main phenomena that contribute technically to the advantages of MicroGroove tubes are (1) reduced boundary layers and (2) increased surface area. 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. Together, both of these lead to dramatic increases in heat transfer.

Slide 10 – Benefits of MicroGroove Tubes (bullet list)

And improved heat transfer results in more energy efficient, smaller and lighter coils…bringing about all of these benefits on our list to the manufacturers and distributors of air conditioning and refrigeration systems. Keep in mind that each of these benefits is not only associated with meeting energy and refrigerant regulations, but each benefit also means cost reductions or cost efficiencies that help all of us in an increasingly competitive market. Advantages like less refrigerant and less material are especially important to cost reduction programs. Let's turn now toward the technology behind MicroGroove tubes and take a look at what happens inside a copper tube with respect to boundary layers.

Slide 11 – 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. So 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. Boundary layers act as an insulator and 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 12 – MicroGroove Features

MicroGroove tubes have internal enhancements to reduce the formation of boundary layers. These enhancements are grooves and 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. And this next slide shows why.

Slide 13 – Reduction of Boundary Layers

In a tube with MicroGroove enhancements, you can see 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 14 – Reduced Tube Diameters = Increased Heat Transfer

When we compare tubes of different diameters, the first thing we might notice is that it will take several smaller diameter tubes to equal the surface area of a larger diameter tube. This is not a disadvantage. We actually have some 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. 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 we will soon see in case studies 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 15 – 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. Looking at this from a different angle, we can handle higher pressures in small diameter tubes with the same tube wall thickness. The bottom line, is that we can do a whole lot more with considerably less material.

Slide 16 – Increased Heat Transfer
So once again I want to emphasize that the reduction of boundary layers and increased surface area are the main technical factors that drive the benefits of MicroGroove tubes. Before we apply these advantages to the actual design and manufacture of coils, let's talk briefly about their impact on energy and our environment.

Slide 17 – Energy Efficiency Ratings
Energy efficiency is typically rated one of 3 ways; the Coefficient of Performance or COP, the Energy Efficiency Ratio or EER or the Seasonally-adjusted Energy Efficiency Ratio or SEER.

Slide 18 – Energy Efficiency Calculations
When we look at how these ratings are calculated, we see that the COP does not have units because both the cooling load, "Q" and the input power "W" are measured in watts.

Slide 19 – Energy Efficiency Calculations
For the purposes of this webinar, we will look at EER ratings. EER ratings are calculated by dividing the output cooling measured in BTU's per hour, by the input electrical power in watts. So the units for EER are BTU's per watt-hour. The SEER rating is the same measurement but it is adjusted to show energy consumption over a typical year of system cooling. EER on the otherhand, covers a single cycle or even a specific point in a system's operation.

Slide 20 – Energy Star Program
Some manufacturers market individual products or even portions of their product line that meet the Energy Star criteria. To qualify for the Energy Star certification, products have to be about 10% more efficient than the minimum federal energy standard. Here we see the current Tier 2 Energy Star specs that took effect on Jan. 1, 2009.

Slide 21 – Energy Star Program
Note the EER qualifications in the Energy Star program. We will be looking soon at performance data from various designs and an EER of 12 gives us a reference point to remember.

Slide 22 – Coil Design Factors
There are a number of factors that a heat transfer engineer can look at when re-engineering refrigeration and air conditioning coils. The factors that we will focus on over the next few minutes are the tube diameter, the number of tubes, the total length of all the tubes in the coil, the number of tube rows in the coil and the number of paths that the refrigerant can take as it passes through the coil. A change in any or all of these factors can affect these coil parameters and measurements.

Slide 23 – Coil Optimization
We call this set of criteria "coil optimization" because the goal of an exercise such as this is to find a set of design factors that provides a more efficient, more compact and less costly coil – a quote-unquote "optimized" coil design, if you will. The first 3 bullet points are all related. The amount of surface area is a direct result of the tube diameter, just as we discussed a few slides earlier. And the amount of surface area will have an effect on the heat transfer coefficient. The heat transfer coefficient, in turn, will drive the overall performance of the coil.

Slide 24 – Coil Optimization (highlighted)
The last 2 bullet points are important because the coil weight and the refrigerant charge will have a big impact on the cost of the coil. So we will pay extra special attention to these numbers.

Slide 25 – Research Partnerships
We are about to look closely at design work done by a research consortium in China for 2 different OEM's. The Shanghai office of the International Copper Association coauthored several papers with the Shanghai Jiao Tong University's Institute of Refrigeration and Cryogenics. The studies we are about to look at were performed by this consortium in partnership with 2 different OEM's who will not be identified by name, at their request, but rather we will refer to them as OEM #1 and OEM #2.

Slide 26 – Split-Type Air Conditioner Designs
In each of the case studies we will look at, the systems being studied are split-type, residential-sized air conditioning systems with outdoor condenser units and indoor evaporator units. Although these units are capable of providing both cooling and heating, you will see that they are very similar to the typical central AC unit that is common in N. America, and this data is absolutely relevant to those systems.

In each case study, several optimized designs were compared to an original design. We will compare in each case the original design to the optimized design that was found to provide the most benefits. A computer simulation program was used to project the performance of many of these design changes. And in order to make sure the simulated results were accurate, the research team first compared actual experimental data to simulated data. They determined that the heat transfer difference between the 2 was only two-tenths of one percent. This proved that the simulation software could accurately predict the performance of the various optimized designs.

Slide 27 – OEM #1 Design Study - Key System Parameters
So let's take a look at the first case study with OEM #1. Listed here are key parameters for the entire system, for both the original design and the optimized design. We can see that R22 is the refrigerant and the cooling capacity of the system is slightly under 2600 watts for both designs. Note that the optimized design has roughly the same cooling capability as the original.

Slide 28 – OEM #1 Design Study - Key System Parameters (highlighted cooling capacity)
Since we are interested in the EER value, we convert the watts to BTU's, and then divide by the input power to get our EER number.

Slide 29 – OEM #1 Design Study - Key System Parameters (highlighted EER)
– and we can see that we are working with a system that just meets the current Energy Star criteria of a minimum 12 energy efficiency ratio.

Slide 30 – OEM #1 Design Study - Key System Parameters (highlighted tube and fin wt.)
And looking at the entire system, a very import factor to an OEM is the weight of the tubes and fins used in both the evaporator and condenser coils because these weights are directly related to cost. And when we do compare the weight of the tubes and fins, original design vs. optimized design, we see weight reductions for the

optimized design in both the copper tube weight and the aluminum fin weight. So we know the optimized design will be less expensive to produce than the original and keep in mind that the optimized design is doing the same amount of work.

Now let's look closer at each of the coils used in this system.

Slide 31 – OEM #1, Indoor Coil Parameters
In the cooling mode of operation, this indoor coil is the evaporator. Let's first compare the factors that we know translate most easily to material costs…

Slide 32 – OEM #1, Indoor Coil Parameters (highlighted tube wall, tube wt. and fin wt.)
And those factors are the weight of the tubes and fins. Looking at the total length of tubes in each design, we see that we have the exact same total tube length for the original design as we have for the optimized design. If we add up the lengths of each tube in the coil, that is the number we are talking about here when we refer to the total tube length. Although those numbers are the same for each design, the optimized design uses smaller diameter tubes, 5mm vs. 7mm. And we see a considerably smaller tube wall in the 5mm tube than the 7mm. The result here is 420 grams less copper in the optimized design. A quick look at the fin pitch tells us that with the tighter spacing of the smaller diameter tubes, we have a denser coil with slightly more aluminum in the optimized design.

Because the tube diameter was reduced in the optimized design but not the total tube length, one might expect the pressure drop in the optimized coil to be higher.

Slide 33 – OEM #1, Indoor Coil Parameters (highlighted tube rows and paths)
But note the number of rows and refrigerant paths. We see that the optimized coil has 4 refrigerant paths vs. only 2 for the original design.

Slide 34 – Indoor Unit Coil Configuration
A quick look at the indoor unit tells us that this coil is long and somewhat narrow.

Slide 35 – Indoor Coil Refrigerant Paths (original design)
We will be looking at several circuit diagrams like this. These are illustrations that we think are a little easier to understand at a quick glance than what we typically see for circuit diagrams. Keep in mind that these are not actual coil images, but just representations of the refrigerant path in these coils.

We see here the circuit diagram for the original design with 7mm tubes and it shows the 2 refrigerant paths. Fairly straight-forward.

Slide 36 – Indoor Coil Refrigerant Paths (optimized design)
Here is the circuit diagram for the indoor coil with the optimized design showing the 4 refrigerant paths. This is much less restrictive path for the refrigerant and will result in a lower, more acceptable refrigerant pressure drop across this indoor coil.

Now let's look closer at the outdoor coil.

Slide 37 – OEM #1, Outdoor Coil Parameters
Just as we did with the indoor evaporating unit, let's compare the original design of the outdoor condensing coil to the optimized design.

Slide 38 – OEM #1, Outdoor Coil Parameters (highlighted tube wall, tube wt. and fin wt.)
We have the same difference in tube wall thickness between the 9.52mm (3/8") and 5mm tubes, but we see a more-than-50% increase in total tube length of the optimized 5mm design. However, because 5mm tubes weigh

less than half of a 9.5mm tube, we see a reduction in tube weight of 435 grams per coil. And in the outdoor unit, the weight of the aluminum fins had dropped by almost 1 Kg per coil.

Now let's look at the rows of tubes and refrigerant path.

Slide 39 – OEM #1, Outdoor Coil Parameters (highlighted tube rows & refrigerant paths)
The heat transfer engineers did something a little different with the optimized design of this outdoor unit. They added another row of tubes but in this extra row the tubes are only half the length of the others. And we go from just 2 refrigerant paths to 5.

This is what they did.

Slide 40 – Outdoor Condensing Unit, Coil Configuration
The original design moves air horizontally through a curved coil made of 2 rows of 9.52mm copper tubes. The illustration here is just showing us the concept.

Slide 41 – OEM #1 Outdoor Coil Refrigerant Paths
This is the circuit diagram showing the paths that the refrigerant travels through this coil. Notice that the refrigerant flows the opposite direction of the air.

Slide 42 – OEM #1 Outdoor Coil Configuration (Optimized unit)
This slide depicts the optimized coil for the outdoor unit. You can now see what they meant by a half-length row of tubes. This design maintains the original concept but uses considerably smaller diameter tubes than the original design.

Slide 43 – OEM #1 Outdoor Coil Refrigerant Paths
Once again, when we look at the 5 paths that the refrigerant can take in the optimized design and compare it to the 2 paths in the original, we can understand how the pressure drop is managed with the much smaller 5mm tubes. The multiple paths offer much less tubing to flow through and therefore a minimal amount of pressure is lost in the process. And be sure to note the nearly identical pressure drop measured in the original vs. the optimized coil. Also, the inlet and outlet now show the refrigerant flowing the same direction as the air.

Slide 44 – OEM #1 Key System Parameters
Summarizing the work with OEM #1, now that we looked so closely at the details, let's look again at those parameters for the entire system. The optimized design offers equal to possibly better cooling with equal input power, no sacrifice to the energy efficiency rating, no sacrifice to pressure drop and all of this with significantly less material.

Let's look at another study – OEM #2

Slide 45 – OEM #2 Key System Parameters
We are looking at a completely different system here but we are looking for the same type of competitive edge with this optimized design. So we will run through this data just as we did for OEM #1.

Slide 46 – OEM #2 Key System Parameters (highlighted BTU's)
Compared to OEM #1, we have a slightly lower cooling capacity…

Slide 47 – OEM #2 Key System Parameters (highlighted EER)
But considerably more input power. So we see a lower EER of 10 compared to the EER of 12 that we had with OEM #1. This system would NOT qualify for the Energy Star program.

Slide 48 – OEM #2 Key System Parameters (highlighted tube wt. & fin wt.)

The optimized design in this system provides almost a kilogram of weight savings per unit on the copper tubing, but we see a slight increase in the weight of the aluminum fin. In real life, this manufacturer found the cost savings from the smaller diameter MicroGroove tubes to be significant enough to justify proceeding with this design in production.

Slide 49 – OEM #2 Indoor Coil Parameters (highlighted tube wall, tube wt. and fin wt.)
Notice here that the optimized evaporator coil goes from 7mm tubes down to 5mm but does so with more total tube length. But once again, due to the lower weight of the 5mm tubes, there is a weight savings of 262 grams per coil. A smaller fin pitch means a denser coil, but the weight savings in aluminum fin material indicates a more compact coil.

Slide 50 – OEM #2 Indoor Coil Parameters (highlighted tube rows and refrigerant paths)
Our optimized design in this case only has 1 more refrigerant path than the original and maintains the same number of tube rows.

Slide 51 – OEM #2 Indoor Coil Refrigerant Paths (original design)
Here is the circuit diagram for the original design of the indoor coil for OEM #2. Already a fairly unrestrictive design with 2 paths. Note the inlet on the left and outlet on the right, giving us refrigerant flow in the same direction as the air.

Slide 52 – OEM #2 Indoor Coil Refrigerant Paths (optimized design)
Looking at the optimized design here, we see 3 distinct refrigerant paths. Again, allowing an acceptable pressure drop with the smaller diameter 5mm tubes. Note the inlet and outlet are now reversed from the original design, resulting in refrigerant flow in the opposite direction as the air.

Slide 53 – OEM #2 Outdoor Coil Parameters
Now let's take a quick look at the outdoor coil parameters. Remember the type of factors we are looking for here.

Slide 54 – OEM #2 Outdoor Coil Parameters (highlighted tube wall, tube wt. & fin wt.)
We see some familiar themes here. Lower tube wall thickness in the 5mm tubes vs. the 7mm, more total tube length with the 5mm tube design but again significantly lower weight. The weight of the fins is almost the same with a slight increase for the optimized design.

Slide 55 – OEM #2 Outdoor Coil Parameters (highlighted tube rows & refrigerant paths)
Looking at the number of tube rows and refrigerant paths we see the same number of rows but interestingly a reduction in the number of refrigerant paths from 5 to 4. Let's try to find out what's going on here.

Slide 56 – OEM #2 Outdoor Coil Refrigerant Paths (original design)
When we look at the original design's circuit diagram we see some "T's" and sharp 90 degree turns in the refrigerant path. When fluid makes a sharp, sudden change in direction like we see happening in this circuit diagram, it can cause a considerable pressure loss and be restrictive to the flow of refrigerant.

Slide 57 – OEM #2 Outdoor Coil Refrigerant Paths (optimized design)
In the optimized design, "T's" and sharp turns are minimized. This less restrictive routing could be one reason why we see fewer refrigerant paths in this optimized design even though we are now using smaller diameter tubes. Note that the pressure drops for the original vs. the optimized designs are nearly the same.

Slide 58 – OEM #2 Key System Parameters
And looking one more time at the key system parameters of this design study, we again see equal performance with less material.

In the 2 studies that we just went through, these OEM's did NOT report the refrigerant charge and that is an important factor in the cost of a refrigeration or air conditioning system. So let's take a look at refrigerant charge data that was collected over the last year.

Slide 59 – Refrigerant Charge is Reduced…
This time the OEM's that contributed the data approved the release of their names. So we see in this chart 3 different manufacturers, 2 different types of systems – window units and split-type systems, and 3 different refrigerants. If you don't recognize R290, that's the name for propane.

Slide 60 – Refrigerant Charge (highlighted original vs. optimized)
When we compare original to optimized designs, we see that the window unit goes from 7mm to 5mm tubes for both the evaporator and the condenser, while both split-type systems reduce from 7mm to 5mm tubes for the condenser coils only.

Slide 61 – Refrigerant Charge (highlighted refrigerant charge & % reduction)
And, as you might expect, it is the window unit that reports the largest percentage reduction of refrigerant charge. But even the smallest refrigerant charge reduction of 20% is still quite sizable and welcome news to the accountant watching the bottom line.

Slide 62 – MicroGroove vs. MicroChannel
All of the comparisons we looked at today have been between different diameters of round copper tubes. Now let's look briefly at a comparison that includes aluminum microchannel tubes.

Slide 63 - LU-VE S.p.A., Italy (highlighted capacity)
This Italian company, LU-VE, optimized an existing condenser with conventional 9.52 mm tubes and reported their findings last year at a conference in Stockholm, Sweden. Although this is yet another completely different study, at this point you can probably pick out the import factors here rather quickly now. "SHVN 19/0" represents the original design and we see that the 2 optimized designs match the cooling capacity rather nicely, all right around 20 kW.

Slide 64 - LU-VE S.p.A., Italy (highlighted tube diameter)
Their existing coil had 9.52 mm tubes and in the trial designs, they used aluminum multi channel tubes and 5 mm copper Microgroove tubes.

Slide 65 - LU-VE S.p.A., Italy (highlighted internal volume difference)
In this row, you can see that they were able to reduce the refrigerant charge in the aluminum tube design to about 51% of the refrigerant used in the existing design. But the 5 mm copper tube design only used about 44% of the refrigerant in the original design, further reducing the refrigerant charge another 16 or 17%.

Slide 66 - LU-VE S.p.A., Italy (highlighted header diameter)
If we look at the size of the header required in the aluminum design, we can see a diameter of 38 mm, which the company reported as the minimum diameter they could use to ensure proper tube-to-header joints and refrigerant flow. A header that size requires a considerable amount of refrigerant to fill that space. And this explains the extra 16% refrigerant reduction with the 5mm tubes compared to the aluminum microchannel.

Before we turn our attention toward manufacturing practices, let's summarize the coil design issues we talked about relative to smaller diameter MicroGroove copper tubes.

Slide 67 – Major Benefits of MicroGroove Tubes
Small diameter 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 68 - Manufacturing
Let me say a few words now about manufacturing practices.

Slide 69 – Tubes and Fins Separate
We all know that coils are made from tubes and fins.

Slide 70 – Tubes Inserted into Fins
And we all know that the tubes are inserted into the fins and then expanded to mechanically fasten the tubes to the fin.

Slide 71 – Tube Expansion…
Tube expansion also ensures good contact between the tube and fin which is critical for the heat transfer that we need.

Slide 72 – Non-Shrinkage Tube Expansion Process
As smaller diameter tubes are expanded, axial tube shrinkage can become a problem. The International Copper Association’s team in China supported the development of cost-effective tube expansion technology that controls tube shrinkage and maintains tension on the expansion tools for high manufacturing yields and long tool life. This technology basically secures the tube end during expansion to prevent shrinkage.

Slide 73 – Benefits
This method of manufacturing coils continues to set the industry standard for corrosion resistance and reliable service life. Since this process remains largely unchanged for small diameter MicroGroove tubes, engineers and technicians throughout the industry are familiar with the practices and also the costs associated with it.

Slide 74 – Game Changer Ad
In conclusion, I want to remind everyone once again to visit the MicroGroove.net website where additional information can be found and questions can be left. We will respond to questions that come in through this website.

Slide 75 – 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 76 – Game Changer Ad (to be shown during Q&A)