MICROCHANNEL TECHNOLOGY

MORE EFFICIENT, COMPACT, AND CORROSION RESISTANT TECHNOLOGY FOR AIR COOLED CHILLER APPLICATIONS

Turn to the Experts.℠

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Syracuse, New York

April 2006

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INTRODUCTION

The air conditioning industry faces a constant challenge to provide higher efficiency levels and greater equipment reliability. This challenge is even more difficult to meet when the goal is to simultaneously maintain equipment size and limit potential cost impact. For example, previous engineering solutions designed to satisfy the above requirements typically have included such changes as improving individual components (e.g., higher efficiency compressors) or increasing the overall heat transfer surface area (e.g., a larger coil) to boost thermal performance. However, each of these enhancements tends to increase equipment size, cost or both.

An alternative solution that is experiencing accelerated use in air conditioning applications, both residential and commercial, is microchannel heat exchanger (MCHX) technology for condenser coil design. This heat exchanger technology has been widely used in the automotive industry for many years on millions of automobiles with substantial success. The focus of this paper is to summarize the benefits that are realized from the utilization of microchannel coils in air conditioning applications. The utilization of microchannel technology for non-automotive air conditioning applications optimizes the benefits that have been realized from the use of this technology in automotive condenser coils.

When compared to traditional coil technology, these benefits include:

- Improved heat transfer and thermal performance
- Increased coil and overall unit efficiencies
- Substantial refrigerant charge reduction
- More compact and reduced coil size
- Minimal equipment cost impact
- Enhanced structural robustness
- Increased reliability as a result of better corrosion resistance

MICROCHANNEL HEAT EXCHANGERS

In the automotive industry, millions of cars use microchannel technology for radiators, air conditioning condensers and oil cooler coils. The utilization of microchannel heat exchangers was initiated in the automotive industry in the late 1980s. With the phase-out of chlorine based chlorofluorocarbon (CFC) refrigerants, the automotive industry was forced to change from R-12 to the environmentally sound refrigerant R-134a. With this change came challenges similar to those faced by the air conditioning industry in achieving the same end result: comfort cooling with a different refrigerant. Refrigerants R-134a and R-12 are two distinctly different refrigerants, each with unique benefits and heat transfer characteristics. When R-134a was used in conventional copper tube/aluminum fin automotive condensers, there was a significant decrease in capacity when compared to R-12.

In the past, attempts to increase capacity have focused on increasing the surface area to accommodate higher heat transfer rates. In an industry in which cost, size and weight are significant concerns, it was important to find an alternative to increasing the surface area. Since the automotive industry could not accommodate larger coil sizes, they required more efficient thermal performance to allow for a smaller heat exchanger that would be more compact and not add weight or size to the vehicle. The industry turned to microchannel heat exchanger technology. This technology takes advantage of established heat transfer principles through the utilization of multiple small-channels in parallel to maximize heat transfer surface contact. More efficient heat transfer results in the ability to maintain or potentially reduce the amount of heat transfer surface required. In addition, the amount of refrigerant charge can be reduced, ultimately resulting in an even more environmentally sound solution when combined with the transition to R-134a.

In addition to benefits associated with thermal performance, the automotive industry was able to realize significant benefits related to the structural integrity of the coil design. Car condenser coils are located directly behind the front grill on a vehicle. Based on the exposure of the car condenser coil to many materials and elements, the rigid microchannel coil construction is better able to withstand oil, salt, material spills, sand, ash, and other chemical road treatments in all types of hot, humid coastal locations, or snowy environments. Furthermore, in contrast to traditional copper-aluminum coils, the aluminum microchannel coil design offers a significant reduction in galvanic attack between the materials of construction. From the use of microchannel heat exchangers in cars, the automotive industry has realized the following benefits:

- Reduced weight, which improves fuel economy
- Smaller components, which occupy less room under the hood
- More effective cooling
- Increased component life

As a result of the overwhelming success of this technology and the associated benefits described, it is estimated that microchannel technology is employed in roughly 75% of all vehicles manufactured and sold today.

CONDENSER COIL CONSTRUCTION

Standard Coil

The standard round tube plate fin (RTPF) condenser coil has copper tubes mechanically bonded to aluminum fins with performance enhancements. Figure 1 shows a cross-section of a copper tube and several aluminum fins. High thermal efficiency is achieved through direct metallic contact between the tube and fin. Sometimes fin enhancements are utilized to improve the fin's air-side heat transfer capabilities. As a result, great thermal performance is achieved with this high-efficiency coil design. The standard coil generally provides excellent performance and long life for non-corrosive environments. Application of this coil in corrosive marine, urban or industrial environments is not recommended unless properly protected with pre-coatings or post-coatings due to the likelihood of visible deterioration and poor long term performance as a result of corrosion.

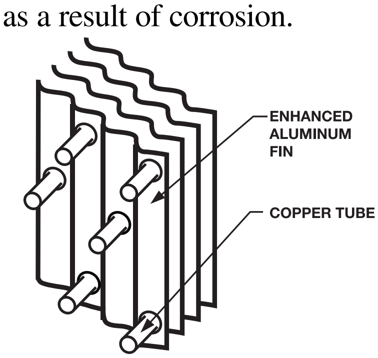

Fig. 1. Standard coil construction.

Microchannel Coil

In contrast to standard condenser coils, microchannel condenser coils are constructed utilizing an all-aluminum brazed fin construction. A microchannel coil is composed of three key components: the flat microchannel tube, the fins located between alternating layers of microchannel tubes, and two refrigerant manifolds. The manifolds, microchannel tubes, and fins are joined together into a single coil using a nitrogen-charged brazing furnace. Overall product quality and integrity are maximized since only one uniform braze in the furnace is required as compared to 200 or 300 manually brazed connections on traditional copper/aluminum coils.

The refrigerant carrying tube is essentially flat, with its interior sectioned into a series of multiple, parallel flow, microchannels that contain the refrigerant (Figure 2). In between the flat tube microchannels are fins that have been optimized to increase heat transfer. The flat tube microchannels are layered in parallel with the tubes connected between two refrigerant distribution manifolds. The coil is divided into two passes. One pass is used to de-superheat and condense discharge gas. The second and final pass is used to finish condensing and provide liquid subcooling (Figure 3).

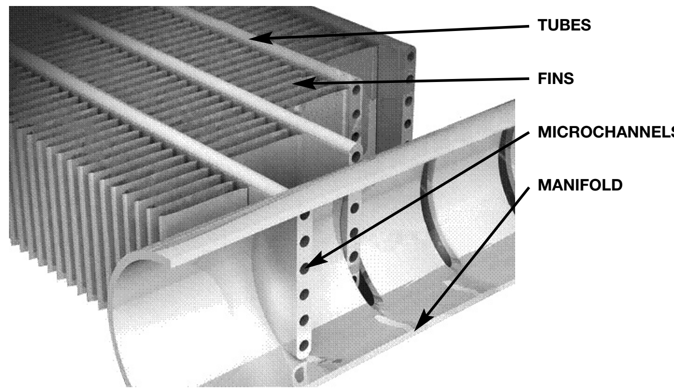

Fig. 2. Microchannel/fin center.

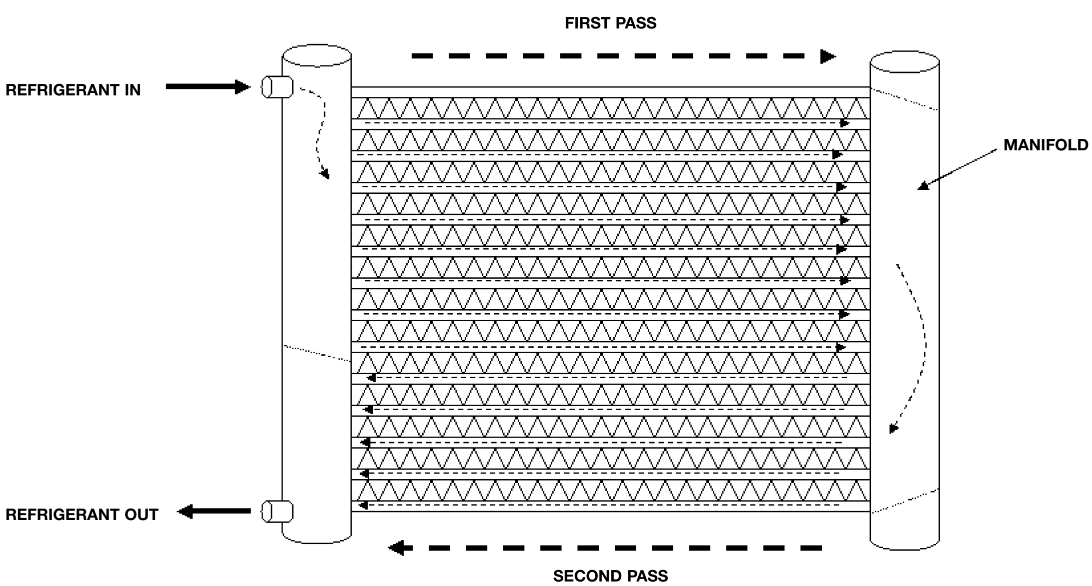

Fig. 3. Microchannel coil construction.

The microchannel tubes in the heat exchanger have excellent heat transfer characteristics on the refrigerant side. On the air side, heat transfer is improved due to the enhanced surface area contact and the metallurgical bond between tube and fin. Fin design is optimized to enhance the fin heat transfer performance (Figure 4). The fin-to-tube bond reduces thermal resistance between the tube and fin, resulting in better heat conduction.

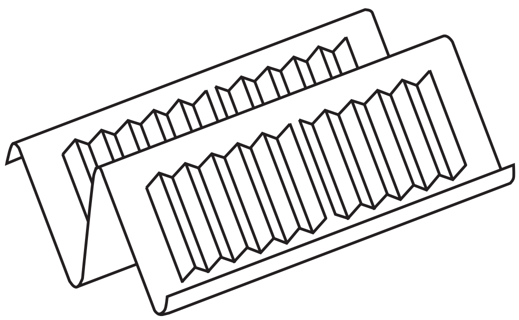

Fig. 4. Fin layout.

BENEFITS OF MICROCHANNEL TECHNOLOGY IN AIR-COOLED CHILLER APPLICATIONS

Microchannel technology will result in better coil and unit performance, which allows for the utilization of an overall smaller coil size and/or increased efficiency. In addition, the coil construction provides for increased levels of structural rigidity and better corrosion resistance. In summary the benefits associated with microchannel technology include:

Thermal Performance:
Performance is significantly better than a standard 3-row, aluminum fin-copper tube coil.

Corrosion Protection:
The rate of the corrosion of the aluminum fins in the microchannel coil is lower than that of the standard copper tube, aluminum fin plate coil due to the material differences within the two designs.

Environmentally Sound Operation:
The single-row coil design with smaller volume also contributes to lowering refrigerant volume by as much as 20 to 40%.

Structural Robustness:
The construction of the coil inherently leads to a more durable coil that is less likely to be damaged. In addition, the single row coil design provides a significant weight reduction opportunity.

Serviceability:
The coil is more easily cleaned and is capable of field repair.

Thermal Performance

The main drivers for the enhanced thermal performance and associated efficiency improvement of microchannel technology are the result of higher air-side heat transfer, higher refrigerant-side heat transfer, and high fin-to-tube surface contact. Microchannel flat tubes create a more favorable heat transfer boundary layer for improving air side heat transfer coefficients which improves overall heat exchange. Also, the microchannel tubes promote better refrigerant-side heat transfer without excessive refrigerant pressure drops. Lastly, the metallurgical tube-to-fin bond increases the contact between the fin and tube, thereby expanding the overall surface area and improving thermal conduction. In essence, enhanced microchannel thermal performance has the potential to permit equivalent system design with up to a 25% reduction in overall coil size when compared to conventional coils. Increased thermal performance from using microchannel technology results in elevated coil efficiency levels of approximately 10% when compared to conventional RTPF technology.

Corrosion Protection

Environmental exposure of air conditioning components can often lead to an undesirable outcome if the correct materials are not applied. Condenser coils are not immune to such factors and therefore, need to be protected from environments that may lead to localized and/or general corrosion. Premature corrosion of heat exchangers, specifically condenser coils, may lead to unexpected performance degradation, poor aesthetics, and possible equipment failure. In order to minimize these effects, material selection and protection schemes must be considered. The environment in which HVAC equipment is applied varies throughout the globe and in some instances, even within a local area. Corrosive environments include coastal or marine climates, industrial, urban, or rural areas, localized micro-climates, and combinations of these conditions. Pollutants within these environments in combination with other factors such as wind direction, humidity, water, time of wetness, fog, temperature, proximity to pollutant source, and dust or particle contamination will result in the premature failure of improperly protected equipment.

The necessary conditions for galvanic corrosion occur when dissimilar metals, in contact, are exposed to an electrolyte. The environment creates the electrolytes necessary for general and localized corrosion of materials. An understanding of the environment in which HVAC equipment is being applied is essential to the proper selection of materials and protection means.

Standard RTPF condenser coil construction utilizes copper tubes in contact with aluminum fins. The use of these two dissimilar materials in harsh environments can result in premature corrosion due to the galvanic couple inherent in this design. In this design, the aluminum fin is less noble (and therefore is less resistant to corrosion) than the copper tube, resulting in galvanic corrosion when the materials are exposed to an electrolyte (created by many environments). The result is attack to the aluminum fin starting at the copper tube/aluminum fin interface. This first creates an unsightly condition. In addition, as the corrosion progresses the performance of the coil is adversely affected due to the build-up of corrosion products at the tube/fin interface (due to the thermal resistance created from the build-up of the corrosion products). The end result is often poor performance in addition to flaking aluminum fins, and depending on the degree of attack, complete removal of aluminum fin material from areas of the coil.

In order to minimize the attack to the standard RTPF coil, several options have been utilized. These include use of pre-coated aluminum fins to insulate the dissimilar aluminum and copper metals from one another, E-Coated aluminum fin/copper tube coils isolating the dissimilar metals from the environment, use of mono-metal copper fin/copper tube RTPF coils eliminating the possibility of galvanic corrosion, and use of E-Coated copper tube/copper fin coils. The mono-metal design has the distinct advantage of eliminating the possibility of galvanic corrosion by eliminating the condition of dissimilar metals in contact. However, this design is not a solution for all environments, since some environments will attack even the copper metal, producing an undesirable result.

The newest technology being employed by several industries to improve heat exchanger design and performance is the microchannel heat exchanger (MCHX). This design utilizes several aluminum alloys, in combination with a metallic coating, for construction of the heat exchangers. The alloys are carefully chosen to extend the life of the coil. The aluminum tube alloy material is initially protected by a metallic layer specifically chosen to be less noble than the tube material, fin and braze material, resulting in any initial corrosion occurring on this sacrificial layer. Furthermore, the coil has been designed so that any galvanic couples within the coil are carefully chosen as to provide the maximum life possible for the coil.

Use of the MCHX in areas in which the standard copper tube/aluminum fin RTPF coil design is typically employed will provide superior corrosion resistance. In addition, while RTPF coils are limited to non-corrosive environments, MCHX coils may be applied in mild marine and/or industrial locations. This advantage, along with the other benefits provided by the MCHX coil (including improved performance, lighter weight, lower refrigerant volume and easy cleaning), makes the MCHX a logical replacement for the standard copper tube/aluminum fin condenser coil.

Environmentally Sound Operation

Scientists have warned that the earth's protective ozone layer is deteriorating due to chlorine emissions from everyday devices that emit chlorofluorocarbons (CFCs), such as R-12, and hydro chlorofluorocarbons (HCFCs), such as R-22. In addition to ozone depletion, another environmental concern is "Greenhouse Gas" global warming, which is believed to be partially the result of CFC, HCFC, and hydro fluorocarbons (HFCs). Officials from the global community have agreed to halt and eliminate production and utilization of chlorine-based refrigerants and to transition to non ozone depleting alternatives, such as HFC-410a and 134a. Along with the enhanced thermal benefits associated with the use of microchannel technology, the refrigerant charge may be reduced by roughly 20 to 40% in a packaged unit application. As such, the use of microchannel coils provides a more environmentally sound solution for air conditioning systems to help reduce the potential for ozone depletion and global warming.

Structural Robustness

The utilization of traditional RTPF coils leads to the potential for fin damage during manufacturing or shipping or after the unit is installed. Protruding aluminum fins from the copper tubes are easily dented, resulting in an unsightly coil surface that appears smashed. If damage occurs, the aesthetic appearance of the coil surface is difficult to repair, since combing or straightening the fins typically does not restore the fins to their original condition. Based on the microchannel coil construction, the surface of the coil is extremely rigid and resistant to damage, even when significant impact is made. Therefore, surface damage to the coil is extremely unlikely.

In addition to structural resilience, the physical properties associated with using an all aluminum construction compared to copper tubes provide a significant weight advantage. This advantage can translate into an overall equipment weight reduction that can significantly reduce installed cost if the equipment is installed on the roof of a building (e.g., chiller, rooftop, etc.).

Serviceability

The structural toughness of the microchannel coil outer surface also makes it easier to clean. Cleaning a traditional copper aluminum RTFP coil with a pressure washer would dent the fins; this is not the case with microchannel coils. The structural rigidity of the coil surface allows pressure washing of the coil, which makes it easier to clean and which can lead to a longer coil life. Furthermore, although the rigidity of the coil makes coil damage or tube rupture less likely, the aluminum flat fin is easier to repair than the aluminum round tube or aluminum fin coils used in the past. Proven and reliable repair methods, using repair kits and standard materials and tools, are available for field repair of a microchannel coil and provide dependable results.

OPTIMIZING THE TECHNOLOGY

Although the microchannel heat exchanger employs an all-aluminum construction, the materials utilized do still create galvanic couples within the heat exchanger. However, the characteristic of the alloys chosen and the specific design of the coil will have a great impact on the life expectancy of the coil. An example of such a design, as described earlier, is one in which the metallic layer on the tubing is selected to be less noble (and first to corrode) than the tube, braze and fin clad material and will serve as the main mode of protection for the clad coated fin, tube, and braze material. This design, along with carefully selected galvanic couples, will provide superior corrosion resistance when applied in environments suitable for the standard RTPF coil.

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 www.carrier.com 04-581005-01 Printed in U.S.A. 04-06