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“THE STAINLESS ADVANTAGE”

Using Stainless Steel Tube/Aluminum Fin Construction in Ammonia Evaporators

Background

Air-cooling evaporators (“air coolers”) used in ammonia systems have traditionally been made using galvanized (zinc coated) carbon steel. There are other metals which exhibit excellent compatibility with ammonia, including stainless steel and aluminum.

Designers and installers of industrial ammonia evaporators must be concerned with the cost, weight, performance, and reliability of the equipment being specified. Additionally, there may be requirements for corrosion resistance, cleanability, and defrosting characteristics, which need to be considered.

Some of the properties of stainless steel make it an excellent choice for tubing in ammonia heat exchangers. It has very high tensile strength, which results in high working pressures. Stainless steel is highly corrosion resistant which minimizes the potential for ammonia leaks in hostile environments. It is readily available commercially and is widely used in the food processing industries for piping, vessels, and equipment. It is also easily repaired in the field by welding.

Negative aspects of using stainless steel in heat exchangers are its high relative cost and very low thermal conductivity. These negative characteristics can be mitigated by: a) specifying the wall thickness of the tubing to match the required working pressure of the system, and b) using another more conductive metal, such as aluminum, as the fin material.

The properties of aluminum make it an ideal metal to use as fin material in ammonia heat exchangers. Aluminum is low cost, lightweight, highly conductive, and corrosion resistant. Since the majority of the surface area in a typical ammonia evaporator is represented by the fins, a Colmac air cooler with stainless tube/aluminum fin construction will have the following characteristics:

1. Low cost
2. Lightweight
3. Good heat transfer performance
4. Fast, complete, energy efficient defrosting
5. Superior corrosion resistance
6. Excellent cleanability
7. High reliability

This article will describe these characteristics, and compare them to galvanized steel, which has traditionally been used in ammonia evaporator construction. Colmac is convinced that ammonia evaporators having stainless steel tube/aluminum fin construction are superior to galvanized steel for most applications. Read on and discover “*The Stainless Advantage*” from Colmac!

Comparison of Properties:

Table 1 below compares several properties of stainless steel and aluminum to those of carbon steel and zinc. Galvanized steel is obtained by dipping carbon steel in a bath of molten zinc, hence these two base metals are shown in the table.

**TABLE 1
Properties of Various Metals**

Metal	Density, lbm/cu ft	Thermal Conductivity, Btu/sq ft h F ft	Specific Heat Capacity, Btu/lbm F	Tensile Strength, ksi
Carbon Steel	490	26	0.107	47
Zinc	445	65	0.094	21
304L Stainless Steel	501	9.4	0.120	70
3003 Aluminum	165	117	0.215	14

The density of the metal directly affects the weight of the heat exchanger, and when multiplied by the specific heat capacity the product indicates the amount of energy required to heat up and cool down the heat exchanger during a defrost cycle.

The thermal conductivity of the metal affects the thermal performance of the heat exchanger, as well as the speed and effectiveness of defrost.

The tensile strength of the metal will determine the burst pressures of the heat exchanger tubes and headers for a given wall thickness. It is interesting to note that various metals behave differently at low temperatures. Carbon steel becomes brittle at temperatures below -20F. Special allowances must be made when designing with carbon steel below -20F such as using special impact tested material, increasing the wall thickness of the pipe, and post-weld heat treating to avoid failures caused by embrittlement of the metal. Table 2 below shows the normal allowable working temperature range for various metals.

**TABLE 2
Normal Allowable Working Temperature Range for Various Metals***

Metal	Allowable Working Temperature Range, F
Carbon Steel (SA-179)	-20 to +500
304L Stainless Steel (SA-249)	-320 to +300
3003 Aluminum (SA-210)	-452 to +400

* Taken from ASME Pressure Vessel Code, Section II, Part D

It is apparent from Table 2 that stainless steel and aluminum offer excellent performance in low temperature freezer applications compared to galvanized steel.

Advantage: Cost

On a per pound basis, carbon steel is lower in cost than both stainless steel and aluminum. This cost differential is offset for aluminum by the metal's low density, so that the cost of aluminum fins is approximately the same as the cost of carbon steel fins. Since stainless steel has such a high tensile strength (see Table 1), the wall thickness of the stainless steel tubing can be safely reduced, which reduces the tubing cost per foot accordingly. The expensive process of hot dip galvanizing is not required for stainless tube/aluminum fin construction, which further offsets the higher cost per pound of these metals compared to carbon steel.

Using appropriately selected stainless steel tubing with aluminum fins produces a coil block which is lower in cost than the same size galvanized steel coil block. A direct cost comparison was made for a coil block 45" high x 162" long x 8 rows deep x 4 fins per inch made for two combinations of materials:

1. 7/8" dia steel tubes with steel fins hot dip galvanized (Stl/Zn)
2. 7/8" dia stainless steel tubes with aluminum fins (SST/Alum)

Figure 1 below shows the calculated costs and weights for the two coil blocks. The stainless tube/aluminum fin coil block (\$3,359) in our example costs 4.9% less than the galvanized steel version (\$3,531).

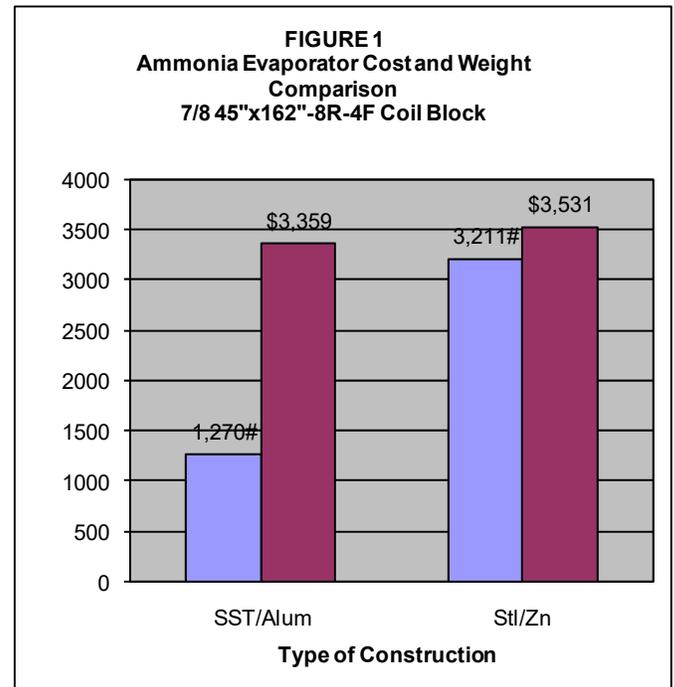
Colmac stainless tube/aluminum fin evaporators offer end users a new cost effective replacement technology for traditional expensive galvanized steel construction.

Advantage: Weight

The very low density of aluminum makes it an ideal metal to use for heat exchanger fins when weight is a concern. Table 1 shows densities for carbon steel, zinc, and aluminum. The densities of steel and zinc (galvanized steel) are approximately 3 times greater than aluminum. In a refrigeration evaporator, the fins represent approximately 1/2 the total weight of the coil block. Most of the remaining weight of the coil block is contributed by the tubes and headers.

Tensile and yield strength of the tubing and header metal will affect the wall thickness required for a given working pressure. The higher the tensile strength, the thinner the allowable wall thickness and the lighter the weight of the tubing. From Table 1 it is apparent that tubing made of stainless steel will have a thinner wall thickness and lighter weight when compared to carbon steel tubing for a given calculated working pressure and burst pressure.

Using appropriately selected stainless steel tubing with aluminum fins produces a coil block that is significantly lighter in weight than the same size galvanized steel coil block. A direct weight comparison was made for the same two coil blocks used in our cost comparison. Figure 1 shows the calculated weights for the two coil blocks.



As can be seen in Figure 1, the calculated weight of the galvanized steel (Stl/Zn) coil block (3,211 lbs) is 2 1/2 times greater than a stainless tube/aluminum fin (SST/Alum) coil block (only 1,270 lbs) of the same size.

Air coolers are often mounted on the ceiling or roof of the refrigerated building. The weight of the air coolers has a significant impact on the structural design of the building and is of particular importance in high seismic areas. Stainless tube/aluminum fin air coolers from Colmac offer architects and engineers a new replacement technology to traditional heavy galvanized air coolers. This weight advantage can be used to significantly reduce the cost of building structural members.

Lighter weight stainless tube/aluminum fin air coolers from Colmac also offer installers advantages when rigging and handling. It is easy to visualize the safety advantages of mounting a stainless tube/aluminum fin air cooler weighing only 2,000 lbs in a building with a 25 foot ceiling compared with a heavy galvanized steel cooler of the same capacity weighing 5,000 lbs or more!

Advantage: Performance

The thermal conductivity of aluminum is 4 1/2 times higher than steel, and 2 times higher than zinc. Thermal conductivity of the fin material has a direct effect on heat transfer efficiency, the higher the better. Aluminum is superior to galvanized steel for efficient heat transfer. Calculated performance of an ammonia evaporator having stainless tubes and aluminum fins is approximately 10% higher than a galvanized steel evaporator having the same dimensions.

The superior cooling capacity of stainless tube/aluminum fin evaporators allows the designer the choice between (a) selecting an evaporator having fewer rows and/or wider fin spacing for lower first cost, or (b) using the same size unit (same rows and fin spacing) and operating at higher suction pressures with resulting reduced operating costs, compared to galvanized steel.

Advantage: Defrost

The high thermal conductivity of aluminum fins also produces faster, more effective defrosts compared to galvanized steel. Stainless tube/aluminum fin evaporators simply defrost faster and better than galvanized steel coils.

Stainless tube/aluminum fin evaporators also perform better than galvanized steel during defrost on an energy basis. A substantial amount of energy is expended during defrost to heat the mass of metal in a refrigeration evaporator up to the defrost temperature, then to cool the metal back down to operating temperature after defrost. When the density of the metal is multiplied by the thermal conductivity the product indicates the amount of energy required to heat or cool a heat exchanger of a given volume by one degree.

Based on this analysis, a comparison was made for our example evaporators. Figure 2 shows the amount of energy required to heat the coil block from suction temperature to 50F and cool it back to down again. This energy is expended every defrost cycle.

As shown in Figure 2, the galvanized coil block (Stl/Zn) consumes significantly more energy (75% more) compared to stainless tube/aluminum fin (SST/Alum) during each defrost cycle. This difference in energy consumption can be converted to cost savings by making assumptions for number of defrosts per day, days of operation per year, and the electric utility rate. A calculation was made comparing stainless tube/aluminum fin to galvanized steel assuming 6 defrosts per day for 365 days/year with a utility rate of \$.06/kWh. Typical screw compressor system COPs were assumed for hot gas defrost. A hot gas defrost pressure regulator setting of 74.3 psig (50F) was assumed. Calculated cost savings for hot gas defrost are shown in Figure 3. Calculated cost savings for electric defrost or water defrost with an electrically heated tank are shown in Figure 4.

As shown in Figures 3 and 4, Colmac air coolers and evaporators with stainless tube/aluminum fin technology offer significant ongoing savings in operating costs compared with traditional energy consuming galvanized steel evaporators. This new development from Colmac represents a breakthrough technology that addresses the urgent need to conserve energy while offering superior performance.

FIGURE 2
Defrost Energy Req'd to Heat/Cool Metal
7/8 45"x162"-8R-4F Coil Block

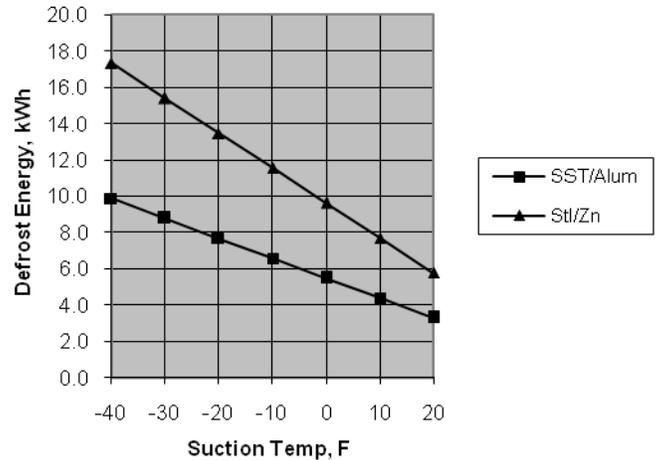


FIGURE 3
Annual Operating Cost Savings SST/Al vs Stl/Zn
7/8 45"x162"-8R-4F Coil Block
(Hot Gas Defrost)

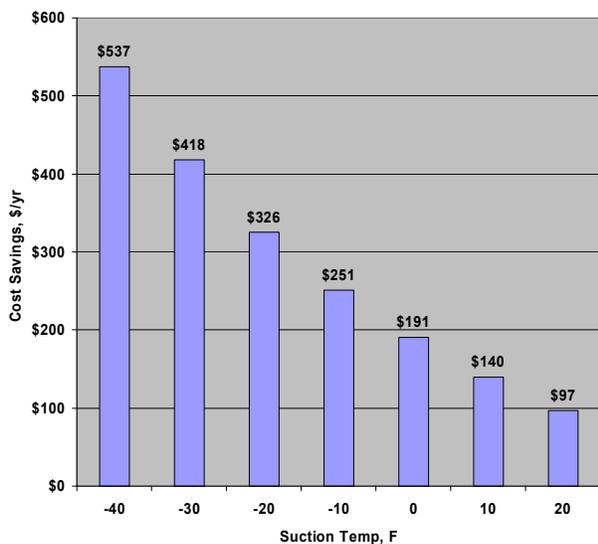
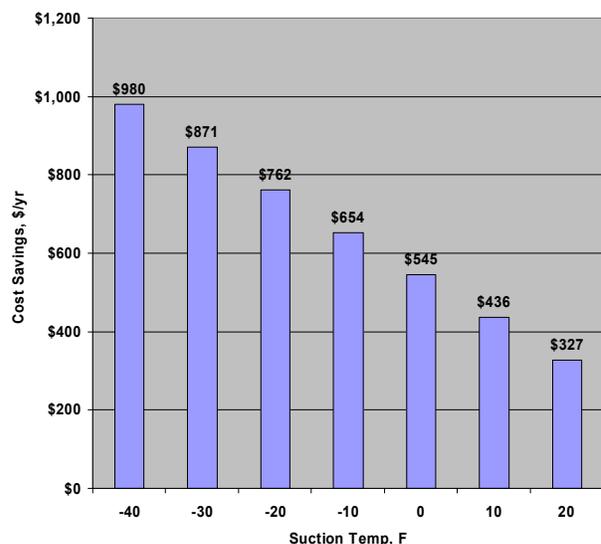


FIGURE 4
Annual Operating Cost Savings SST/Al vs Stl/Zn
7/8 45"x162"-8R-4F Coil Block
(Electric or Electrically Heated Water Defrost)



Advantage: Corrosion Resistance

Corrosion of heat exchangers by contact with, or proximity to foodstuffs is a concern in food processing facilities. All foodstuffs are mildly acidic. Aluminum and stainless steel are both more corrosion resistant than galvanized steel when exposed to acetic and citric acids (dairy products, citrus products), fatty acids (anti-caking agents, lubricants), and lactic acids (bread, confections, beverages, fermentation, blood).

Aluminum is more corrosion resistant than galvanized steel in the presence of sodium chloride (preservation of meats and vegetables), and sulfur dioxide (grape storage). Neither galvanized steel nor aluminum is recommended for exposure to nitrites (cured and smoked meats). Stainless steel is the suggested material to use in the presence of nitrites.

Generally speaking, aluminum and stainless steel are better metals to use than galvanized steel where there is concern about corrosion due to contact with most foodstuffs.

Advantage: Cleanability

Cleanability of equipment in food processing facilities, including evaporators, has become an increasingly important issue. Bacterial contaminants must be removed with regular cleaning and locations where they can accumulate need to be minimized.

The smooth, hard surfaces of stainless tube/aluminum fin evaporators are ideal for effective cleaning in food processing equipment and facilities. The rough, porous surfaces of galvanized steel evaporators may present difficult cleaning problems for operators in facilities where bacteria-free operation is critical. To address this important issue, Colmac offers this new stainless tube/aluminum fin construction with continuous plate fins as deep as 16 rows. This feature eliminates splits and gaps between fins where food particles and dirt can accumulate.

Advantage: Reliability

Since 1984, Colmac has excelled in manufacturing air-cooling evaporators of many types for ammonia refrigeration systems. Only the best quality tubing is used. 100% of this tubing is eddy current tested at the Colmac factory prior to assembly into evaporators, insuring zero-defects. All tube joints are carefully joined by a special TIG welding process, then pressure tested at 500 psig to insure absolutely no leaks.

The excellent corrosion resistance of stainless steel tubing used in Colmac stainless tube/aluminum fin evaporators offers superior reliability compared to galvanized steel. As a result, Colmac offers a full 5-year warranty on any stainless tube/aluminum fin coil block manufactured by the company (see Limited Extended Stainless Steel Tube Coil Block Warranty for terms and conditions).

Conclusion:

With stainless tube/aluminum fin construction, Colmac has introduced an exciting new breakthrough technology for evaporators in ammonia refrigeration systems. The analysis above has shown stainless tube/aluminum fin construction to be superior to traditional galvanized steel on the basis of:

1. Cost
2. Weight
3. Performance
4. Defrost
5. Corrosion resistance
6. Cleanability
7. Reliability

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