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Stainless Steel Tube Coils for Use with Ammonia

A personal view of European developments since 1965


Stainless Steel Blast Freezer coil for use with Ammonia

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The use of thin wall stainless steel tubing with bonded aluminum fins for use with ammonia is far from new. It was introduced both as an evaporator and as an air cooled condenser as far back as 1968 and, after some skepticism and a hesitant start while manufacturing problems were overcome, it took a modest but significant portion of the ammonia market during the next twelve years.

The products were successful, their advantages were recognized, there was no legacy of problems and many will be over 30 years old by now. That production was halted, was due to the sale of the company to another with a lesser interest in ammonia and that they did not achieve a greater impact upon the scene was probably due to the following reasons:

The ammonia market was in decline. Ammonia was perceived as being dangerous, old fashioned and belonging in the past. The future belonged to the fluorocarbons and hydrofluorocarbons which permitted the uses of lightweight, high efficiency coolers, not heavy galvanized coils.

Progressing only largest ammonia plants which were expensive to replace were left. These were almost invariably pump circulation with perhaps 10% gravity fed.

Then in the early 1980's a hole was discovered in the ozone layer! Ammonia began a remarkable recovery which shows no sign of abating. Part of it's success is due to the new generation of lightweight heat exchange products but to the new generation of lightweight heat exchange products but to this must be added changes in system design and, in particular, the increasingly widespread adoption of the low charge Low Pressure Receiver (LPR) system. Highly successful with R-502 and R-22 and despite difficulties that were not experienced with HFCs, LPR is now recognized (in the U.K. at least) as the major player in the ammonia field. See **Figures 1** and **2**.

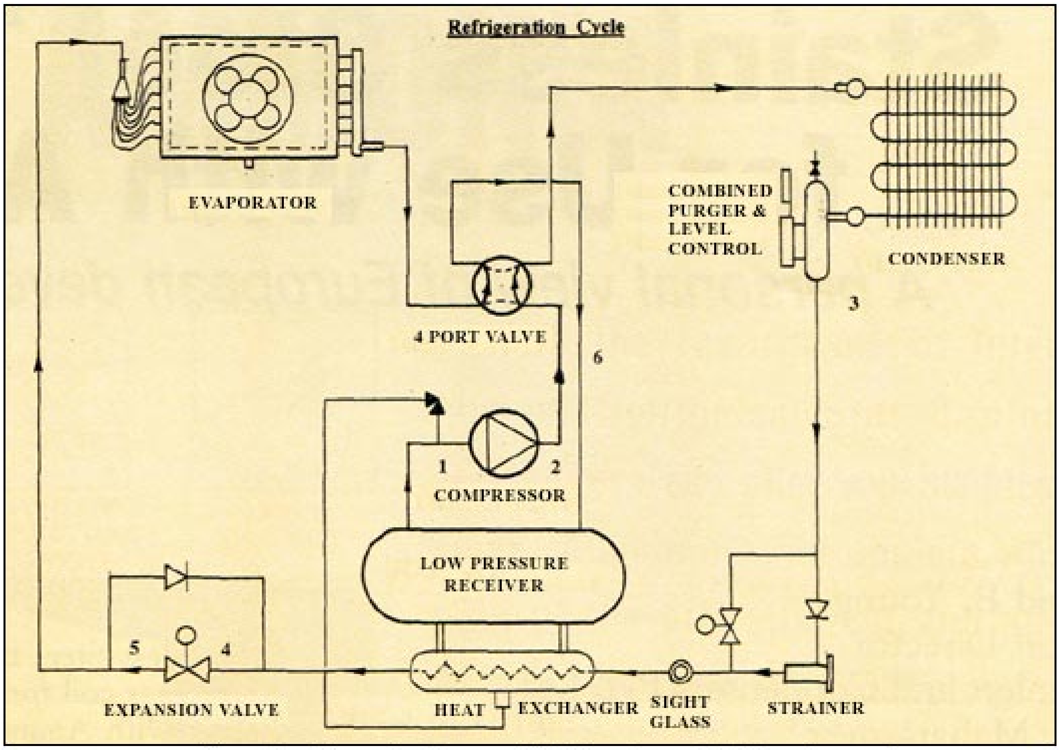

Figure 1 : Schematic diagram of LPR system on Refrigeration cycle

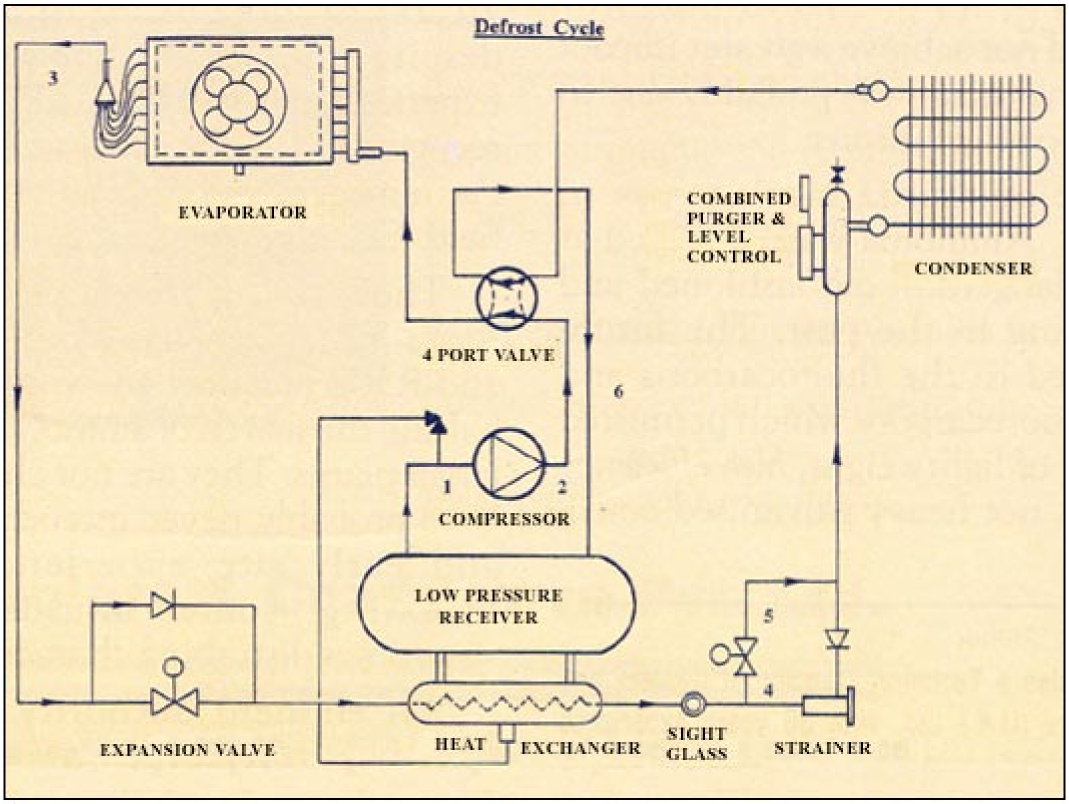

Figure 2 : Schematic diagram of LPR system on Defrost cycle

There is, it is true, a plethora of "drop -in" replacements for R-12, R22 and R502 but they show no sign of halting the march of ammonia on the larger plants. They are not cheap and were probably never intended to be and early site experiences re revealing some unusual and sometime disturbing characteristics.

An eminent authority on the world refrigeration scene demonstrated at a scientific symposium, perhaps with tongue in check, the virtues of Propane as a replacement for R12. The domestic refrigerator before his audience had been evacuated and recharged with this excellent gas and the drinks within were delightfully cold. It would work even better, he claimed, with some minor modifications. But there was, of course, one major problem - it was dangerous!!

So saying he took from his pocket and brief case, first a cigarette lighter (Propane clearly visible) and a ladies hair spray, the propellant of which we were asked to take on trust. His conclusion was that Propane could not hope to have a place in the new order of things because *there was no money in it*!

Some of the R502 "drop-ins" are currently showing some of the unpredictability of R502 in it's early years. R404A and R69L (drop-ins for R502) are suffering from oil and refrigerant logging problems are occurring at the same time as a major rethink on the virtues of how gas tray defrosting on large ammonia coolers (Further comments later).

Ammonia is comparatively cheap, its performance is unrivalled as a refrigerant, it is ideal for large plants, but the advent of the LPR system means that much smaller individual plants are a very real option. Finally, ammonia is seen as being totally "green". (Multi-national supermarket chains are much concerned with their corporate "image" and sales might plunge were it to be found that they were it to be found that they were using an "environmentally unfriendly" refrigerant)

Thanks to an industry inspired Code of Practice for plant and installations, the element of risk has been all but eliminated and it was ever the case that the risk of being asphyxiated by freon is greater than dying as a result for the toxicity of ammonia - a few parts per million and you run a mile!

Ammonia thrives as a direct refrigerant, commonly in pump circulation (almost nil gravity fed) Direct expansion, TEV controlled evaporators were tried but did not succeed. The TEV's were unreliable and a major problem was uneven liquid distribution at the evaporator. Ammonia being such an excellent refrigerant, offers by comparison with the HC's and HFC's, such a miniscule rate of liquid flow that there is nothing for the liquid flow that there is nothing for the liquid distributor to "get it's teeth into". Poor liquid distribution on a TEV controlled evaporators means a massive drop in performance, add to this the inevitable temptation to try DX on the smaller coolers (even less liquid flow?) which might be situated some distance from the central plant on a pump system and you had a recipe for disaster. It is, thank goodness, no longer attempted.

The greatest change, at least during the last few years, has been the spread of the overfed DX with a reverse cycle defrost evaporator used in conjunction with a low pressure receiver system. It worked well with R502 and R22 and, whilst it's translation to ammonia is not recent nor has it been achieved without difficulty, it is only in the last five years or so that it has made the strides that it has.

There will be always be advocates of the ammonia pump system but LPR with the cooler now freed the reverse cycle defrost tray in favour of electric and with recent coil circuiting developments which have eliminated defrost gas wastage, has emerged in the U.K. as the clear favorite.

Plants are invariably four port reversing valve with a reverse cycle defrost. This is sure and it is quick, as is air temperature recovery. Writing here in India precise statistics are not to hand, but I guess that of the total output of the C&C. U.K. Ltd. Plant, ammonia products during the last 18 months. 75% to 80% has been for LPR use and the trend cannot be shrugged off as a statistical aberration.

It would be out of place here to do more than pass on without comment the claims for LPR, it is not the job of the heat exchanger manufacturer to know those of others, but we see no reason to contest them.

It is claimed that:-

- It is simple and highly efficient.
- It lends itself to a wide variety of plant sizes.
- It works well with ammonia but even better with the halocarbons.
- Reverse cycle defrost is more effective than hot gas defrost because, during defrost, there is no need to maintain an artificially high condensing temperature.
- The two pipe system is simple and cheap. The four port reversing valve is less likely to leak than valves used in hot gas systems but, should leakage occur, an experienced engineer will spot the give-away frost pattern
- There are significant savings in refrigerant charge.
- It provides the smallest practical cooler design combined with the lowest suction line pressure drop.

(Overfeed is achieved at the evaporator by liquid sub-cooling not by pumping excess liquid).

- Perhaps most important, in the area of cold storage, independent reviews have shown significant increases in efficiency over pump circulation together, obviously, with equivalent power savings.

The point to be made about LPR is that the system and the lightweight stainless steel coil match each others defrost characteristics extremely well land this may well be why all the major ammonia cooler manufacturers are either offering stainless tube/aluminium fin coolers or are trying to develop them but the construction has equal advantages for flooded or pump circulation ammonia.

So far nothing has been said about ammonia's other strength which is as the primary refrigerant in an indirect system and here too there has been progress. Propylene glycol, ethylene glycol (non-food applications) but principally Tyfoxit® one of a new generation of low temperature fluids, are frequently used in personnel sensitive areas. The ammonia plant is confined to a secure site and with 'glycol', or a variant, the cooler control land its performance is predictable and assured. Finally, a new development of "Integrated Electric Defrost", either located within the cooler or perhaps in the ceiling space immediately above it, is replacing the remote heated tanks and extensive pipe runs of earlier plants. For applications in India a heat exchanger to collect solar heat would relegate electric heating to that of a cool weather top-up.

This may be the place to say something about drainpan defrost. It has been a tradition of hot gas devotees to reject the idea of using electric elements in the tray and there is much to commend the view that, with adequate hot gas, the use of electric power is wasteful. All of this is true but there is another side to the coin. (And here must be emphasized that the points now to be made are more relevant to Europe than to India where coolers are much smaller and tray construction simpler - but the principles are still relevant and there may perhaps be pointers for the future.)

Defrost are a necessary evil! All defrosts waste power as they heat metal, heat air and frequently inject excess moisture into the store to become snow and ice - and it all has to be clawed back when the defrost has finished. Defrosts which drag on waste still more power; the top of the coil will invariably overheat as the defrost struggles to move stubborn ice at the lower level, as it heats up, the convection (chimney effect) losses rise sending yet more moisture to deposit on ceilings and floors; worse still the increase in convection exacerbates the problems at the base of the coil as more air at sub-zero temperature is dragged onto the exposed fin face. It has become a vicious circle.

The tray so often compounds the problem. On LPR reverse cycle systems the tray tubes are the first part of the suction line and, at the commencement of defrost, the first problem to be faced by entering defrost gas is the remnants of refrigerant overfeed which must be boiled off before the coil defrost can valve leakage may result in liquid refrigerant lying the tray; it should not be there and is rarely detected until it has become serious but it often leads to a coil defrost problem. As coolers have increased in size it seems that tray problems have mounted but, whatever the cause, the entering gas should be given the best chance of defrosting the coil, it should not have to expand it's energy on boiling off refrigerant or melting even small amounts of tray ice. The penny seems to have dropped! (meaning, that it has now dawned on designers)

The penny seems to have dropped! (meaning, that it has now dawned on designers) Put a few elements in the tray, they may even be controlled by a separate time clock, retain all your heat for the most important thing of all which is the coil, defrost it fast to save power and to stop pouring moist air into the store. Send the moisture down the drain not into the room and stop turning he area near the room and stop running the area near the coils into a Greenland grotto! Finally, and this is relevant to India, electric trays are cheaper.

Before discussing the merits or otherwise of he stainless steel cooler, a word about safety may not come amiss. C.&C. U.K.Ltd was established in 1983 and despite earlier experience the participants were not at the time moved to enter the ammonia field. With the resurgence of ammonia they decided to look at all possible construction possibilities but they eventually returned to their earlier field of experience, stainless steel. However before they did they visited the Swinden Laboratories at Rotherham U.K., the research home of British Steel Stainless Division. There they placed before experts the proposed method of manufacture, it was commented on and a few changes made but, what emerged then was what has been used with some manufacturing improvements, for the past thirteen years. In particular, and in comparison with the earlier generation of coolers, the coil joints are now a total fusion of the overlapping tube surfaces and this makes for an almost complete absence of "pin holes" found at the test tank and a record of outstanding reliability. No filler rod is used on the stainless-to-stainless joints and the fused joint is, as a result, some four to five times stronger than the earlier generation joint.

Concern is sometimes expressed at the primary tube wall thickness (0.5 mm). It is not thick but it is more than thick enough and its thickness should not be compared with the softer mild steel options. It must of necessity be thin for to increase he wall thickness will, first and foremost, increase drastically the problem of mechanical expansion which always was and still is if consequence. Further, a thicker wall would reduce he heat flow; stainless steel is a poor conductor of heat but the very thin wall means the overall conductivity of the stainless/aluminium coil is less than 1% interior to copper/aluminium. So far as accidental damage is concerned, stainless is tougher than mild steel and will cope with reasonably heavy handling. The author can recall no ammonia loss through accidental (physical) damage in the history of the product.

Standard products are tested at the conventional 420 psig (28bar) air under water but they will go much higher. A stainless tube air cooled condenser for use with carbon dioxide at an occasional 960 psig tested very happily at 1600 psig. The bare 15 mm, 0.5 m wall thickness tube, unsupported by fin collars shows no sign of any distortion below 3000 psig it needs in excess of 3600 psig to achieve that.

Finally it is worth mentioning the matter of Lloyds Approval. Large stores require product insurance and a Division of Lloyds Register of Shipping has for years set standards for plant and installation for "Approved Stores". This caused something of a problem in early years because no standard nor specification existed for stainless steel tube construction. This difficulty was, with the assistance of Southampton University who were involved in drawing up the specification and who 'destruct test' operative's sample joint as part of their annual approval, resolved and is the basis for all new stainless construction.

Comparison of ammonia finned/coil derivatives

Given below is a comparison of the more commonly used ammonia products of which some are in much more common use than others. The comments are of necessity generalization and once again they are based upon European experience and, in particular, the U.K. refrigeration contractors who, in the main, can choose wheat they buy. It should also be explained that, for reasons which are not easily to understand, the U.K. market and much of Europe has for many years been almost completely dominated by the all galvanized steel product, so it is against this background that the changes in the ammonia field should be viewed.

It may help to explain some of the terms used.

• **Robust** -Ammonia plants normally are industrial in scale and coolers are likely to come in for heavier treatment than their commercial cousins. They are normally permanently staffed and it may take time to convince the resident engineer that lightweight coolers need more considerate treatment.

• **Hygienic** -For better or worse there is in the European Union a tidal wave of food hygiene regulations.

The U.K. seems to take these seriously with the result that food producers have to have visible and verifiable cleaning regimes for production and storage rooms, and, since they are part of the furniture of a room, the cooler. The Supermarket Inspectors are all powerful and hey have the power to wipe a company from a list of suppliers at the drop of a hat; which leads to a problem.

Many fin/tube coils are made from dissimilar metals and these may suffer from electrolytic corrosion under certain conditions. Unfortunately the mechanism of this is not always understood. Many biocides and cleaning fluids are heavily alkaline and this can have a devastating effect and this can have a devastating effect upon the coil, particularly the copper/aluminium combination. It is very difficult to convince a distraught store owner who is using a cleaner which is "safe for use on aluminium" that the reason for the disintegration of the aluminium fins is that when they come into contact with copper, the rate of corrosion will accelerate by some 20,000%! He suspects the fin materials at fault.

• **Corrosion** -There has been a revolution in family work and eating habits. There is a huge market in prepacked sandwiches and many fillers are corrosive. The casing of a normal cooler may be wrecked after six months in a mayonnaise store; likewise the explosion in popularity in Indian cuisine has been a mixed blessing - the plating of cooler fastenings above a warm vat of that perennial British favorite, chicken tikka will last less than three months. Everything must be stainless steel.

The comparisons between the four most common ammonia coil options are less the personal view of the author, more apparently the perceptions of the European and particularly, U.K. market, during recent decades. Everyone has their favorites but given below is what seems to be an average view (if such can ever exist).

1. Mild steel fin and tube -galvanised after manufacture

Advantages:

- Extremely robust, both fin and tube.
- Long history of trade acceptance and reliability.

Disadvantages:

- Extremely heavy - limiting its potential as a ceiling mounted product.
- Heavy coil leads to longer times for defrost and temperature recovery.
- Unhygienic - at least in that the surface finish of the zinc galvanizing is fat from smooth. This may sound trivial but that is the perception.

2. Aluminium fin and tube

Advantages:

- Excellent conductor of heat.
- No dissimilar metal fin corrosion problems. Some agents will attack aluminium but their effect on plain aluminium will be much less than on that in conduct with a different metal (particularly copper)
- Light and efficient.

Disadvantages:

- Tubes are comparatively easy to damage.
- Aluminium has generally been used with pumped or flooded system with large diameter (22 mm) tubes. As such they would not suit LPR systems which require smaller 15 mm tube.
- They cannot be repaired at site. Once damaged, an ammonia coil is generally considered a "write-off".

3. Mild steel plated (electroplate or galvanized)tube with bounded aluminium fin

Advantages:

- Light.
- Efficient.
- Reasonably quick to defrost and recover.

Disadvantages:

- Unhygienic. (Tube surface)
- Potential corrosion risk to coil tube (from cleaning agents) particularly under fin collars.(it is difficult to obtain a comprehensive view of this genre of construction because such a small proportion of the U.K. market.

4. Stainless steel tube and aluminum fin

Advantages:

- Lighter than copper/aluminium.
- Strong (tubes). Much stronger than copper (but less than heavy galvanized)

- Can be modified or repaired at a site. A portable argon are welder can and has been used 10 m. above the floor and at minus -35°C.
- Quick defrost and air temperature recovery times.
- Light weight offers opportunity for extra large coolers at high level without support steel penalties.
- Large coolers offer best opportunity for substantial air throws and reduction in fan power used.

Disadvantages:

- Fins are aluminium and need reasonable handling.
- Potential for dissimilar metal corrosion. (Stainless/aluminium is 45% less prone to this than copper/aluminium).

Summary of advantages for stainless steel tube/aluminium fin coils

Once more the point has to be made that there is, at present, a world of difference between the needs of India, certainly at this time, and the U.K. There, the "out-of-town" supermarket is king and it is so because customers almost all have cars. Supermarkets are enormous and are supplied by distribution store are supplied by distribution stores which again, for reasons for efficiency, have become bigger and bigger. The 'norm' is 10 m. high and a large room could contain three football pitches and be served by 20 coolers each 10 m. long/. Wage costs picture that handling is as mechanical as possible, usually by high reach fork trucks.

Air movement is achieved for minimum fan power by the use of low speed (8 or 10 pole), large diameter (910 mm) fans, perhaps 6 per cooler which represents substantial air momentum. Air throws of 100 metres or more may be needed and this can be achieved by use of cooling and wall surfaces and the grouping of cooler in pairs (double the momentum). Contrary to popular misconception, good air movement is much more easily achieved by halving the number of coolers and by careful positioning - air throw is about creating an air pattern in which the air-return-path is as important as he leaving one.

As India's Cold Chain comes into being so some of this may be of interest. At present, from the Author's limited visits, the stores seem to be multi-story manual handling, having slatted floors and, using small to medium size coolers which seem to be very effective. But, whilst stainless steel has provided a generous like in cooler size, this is only one advantage.

The time taken to defrost a cooler is time lost and power uselessly expended. That time is made up of a number of processes but the main one is raising the coil mass from working temperature to above freezing and the sheet mass of the coil must be a factor. A stainless/aluminium coil is one third of the weight of the all galvanized construction and there is a significant saving, after defrost we have a tin box part full of warm air plus a mass of warm metal. The air is thrown out into the store (the quicker the defrost the less heat back to the room) but the metal mass must be dragged down once more. It all takes time and its all wasted power. Add to this that whilst some coolers are on defrost those that are working less efficiently and the importance of defrost speed becomes significant.

Much emphasis is given to power consumption when assessing plant efficiency and rightly so but the area of down-time during defrost may well be one in which improvements could yield a worth while harvest.