ALUMINIUM ROLL BOND- A SINGLE INNOVATIVE CIRCUIT FOR AIR CONDITIONER, CAR RADIATOR, REFRIGERATOR AND WATER HEATER.

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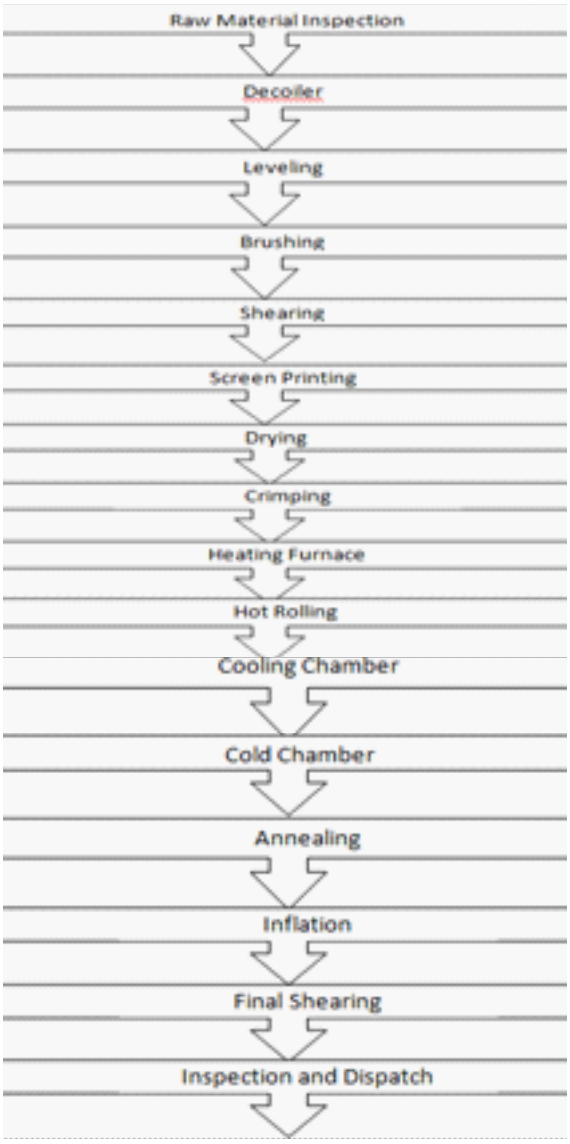
01 Introduction:

In almost every industry, home and every institution now a days air-conditioning, refrigeration is necessary. Whether be it a high profile mechanical company or a highly equipped computer lab. Refrigeration and cooling is necessary. Hence refrigeration and air-conditioners come into picture. There are, obviously, a lot of basic parts in the main unit used. One of the basic components is evaporator .This is what M/s Annapurna Earcanal Ltd Produces. In this paper process of roll bonding is described inspection stages and defects are highlighted. Aluminum roll-bond evaporators provide unique design flexibility for direct cooling refrigeration systems. Roll bond evaporators deliver efficient thermal performance in a product that can be shaped to fit most applications. Whether the product requires a sample flat panel or a multi shaped evaporator, the company's engineers will collaborate with the clients closely to develop the best solution. References 1 -5 give an outlook on this process.

2. Connectors:

Rolled Aluminum sheets with circuit printed on them using special chemical ink are inflated with air as the medium. Production Mechanism: The process of roll bonding aluminum sheets to a tube and plate heat exchanger is described below as shown in Flow Chart 1. (3.1-3.9)

Flow Chart of Roll bond



Flow Chart 1: of Roll Bond Process (3,4,5)

3.1 Pre-Part inspection:

After the raw material is unwrapped the thickness and width of the aluminum sheets are checked and compared to the requirements. The sheets are also checked for the edges burs. Finally, the waviness, the surface and the physical condition of the sheets is checked. The process takes about 5 minutes.

3.2 Decoiler and Leveler:

The decoiler uncoils the sheets from the spindle and the sheet is then leveled to set the waviness of the sheet. Both the processes together take about 15 minutes.

Photo 1: Decoiling & levelling processing section

3.3Brushing and shearing:

Brushing is done to facilitate bonding between the aluminum sheets. It removes dust from the surface of the sheets and gives them a dull finish. Shearing is done to cut the coil into individual pieces as per the required size. Both the processes together take 1 minute

Fig: 1 Dimensional Specification

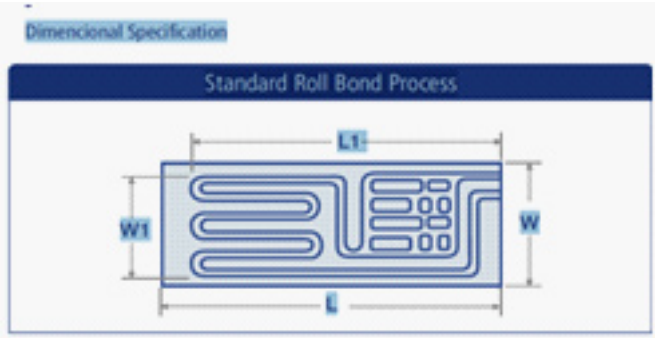


Table 1: Design Limitations

	Table and Design Limitations (mm)			
	W (max)	L (max)	W1 (max)	L1 (max)
Inflated	780	3440	730	3340
Stamped	780	3000	730	-
Painted	780	2200	730	-

Fig 2: Two sided inflated cross section

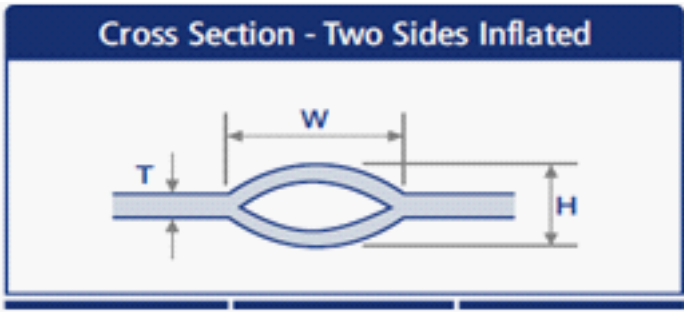


Table 2: Design Limitations

T (mm)	H (mm)	W (mm)
1.1 / 1.2	3.8	6.0
		8.0
	4.0	9.0
		10.0
1.3	3.8	6.0
		8.0
	4.0	9.0
		10.0
1.4	4.0	9.0
		10.0
	4.6	11.0
1.5	4.6	9.0
		10.0
		11.0

3.4 Screening printing:

Screen printing is done via R-134a compatible process .The circuit is printed on the sheets as per the drawing provided by the customer .The process takes 1 minute.

3.5 Drying and Crimping:

After printing, the sheets are dried in the oven .Dried sheets are crimped together at one end to hold them together, one with the design printed on it, one plate. The process takes about 3 minutes. The sheets are then sent to the heating furnace.

3.6 Heating furnace:

There are two heating furnaces: an electrical furnace with the two zones (Zone 1 with temperature of 6380C, Zone 2 with temperature 6390C) and a gas furnace (of temperature 7120C). The sheet is heated up to 4700C approximately for 15 minutes to facilitate better bonding between the sheets.

Hot rolling and cooling chamber:

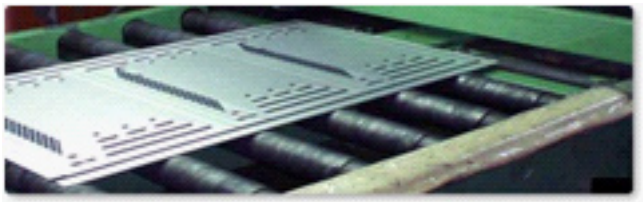
The sheets are sent to the hot roll as soon as exciting from the heating furnace. They are expanded to 150% of the original length and thickness is reduced hot rolling takes about 1 minute. The expanded sheets are then cooled to room temperature in the cooling chamber for 10 minutes.

Photo 2: Hot rolling and cooling chamber

3.7 Cold rolling and Leveler:

After cooling , the sheets are sent to the cold rolling mills where they are expanded to thrice the length .The length of the sheet is achieved as per the drawing by passing the sheet between two rollers . All rolled sheets are to be leveled to improve the shape of the sheet. It takes around 1 minute .The length of the cold rolling sheet after cold rolling in the product of the length of the sandwich and the reduction ratio with a clearance up to 85 mm.

Photo 3: Cold rolling process



3.8 Annealing:

Annealing, in metallurgy and materials science, is a heat treatment wherein a material is altered, causing changes in its properties such as strength and hardened. It is a process that produces conditions by heating to above the recrystallization temperature, maintaining a suitable temperature and then cooling. Annealing is used to induce ductility, soften material, release internal stresses, refine the structure by making it homogeneous and improve cold working properties.

In the cases of copper, steel, silver and brass, this process is performed by substantially heating the material (generally until glowing) for a while and allowing it to cool. Unlike ferrous metals, which must be cooled slowly to anneal; copper, silver and brass can be cooled slowly in air or quickly by quenching in water. In this fashion the metal is softened and prepared for further work such as shaping, stamping or forming

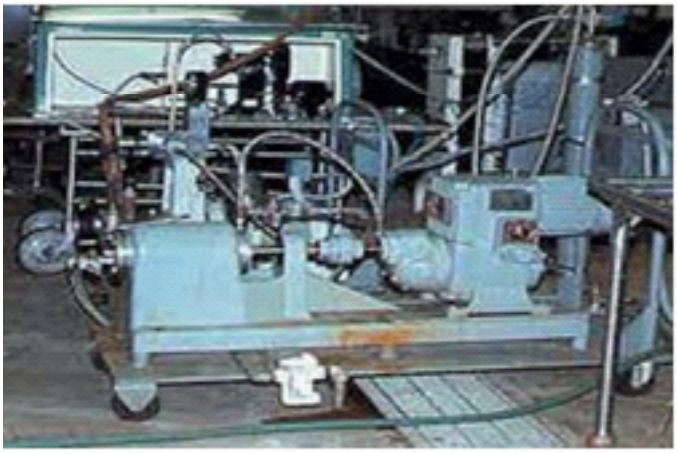
Photo 4: Aluminum Annealing Furnace

After the expansion ,the sheets are sent are sent to be annealed , spending 4-4.5 hours in the annealing chamber followed by 24 hours of cooling .Annealing is done to relieve stresses due to work hardening and thus preventing cracks in the sheets while inflation is being done.

3.9 Inflation and shearing:

After rolling and annealing, the two sheets are bonded at places where there is no ink. Air at a pressure of 100kg force is sent through the sheets which cause the printed circuit to be inflated .Inflation takes 1 minute.

Photo 5: Shearing & Inflation process



Final shearing is done as per the drawing of the customer, the length and width required will be given in the drawing and as per the specifications mentioned in the drawing the stoppers are set for the shearing operation .It takes about 5 minutes for the shearing process.

Photo 6: Inflated, Stamped, welded & painted

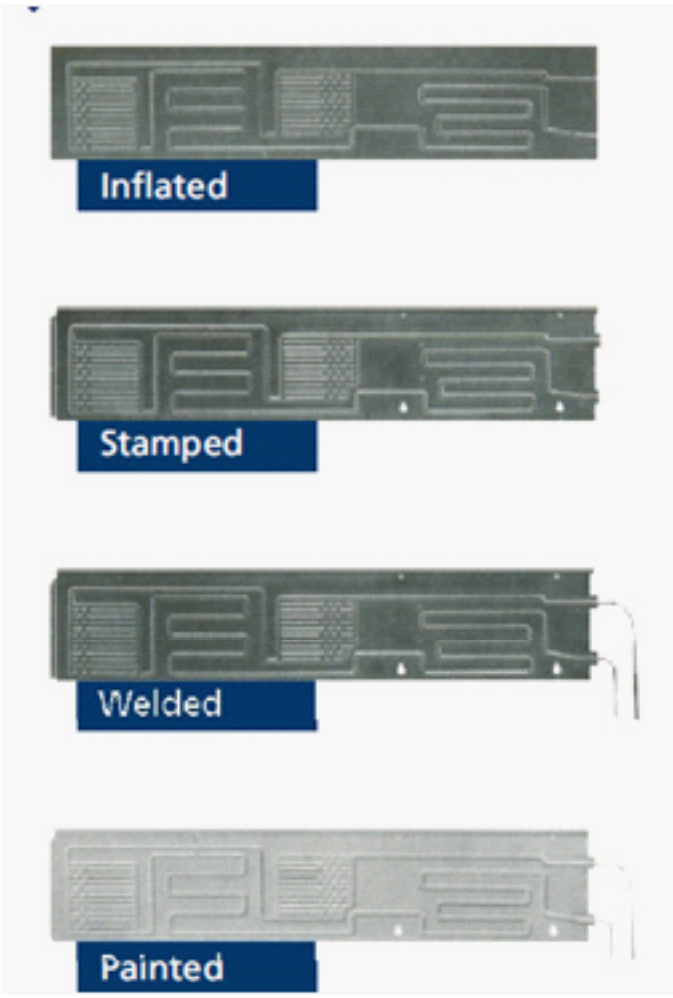


Table 3: Mechanical Properties & Paint Specifications

Mechanical Properties

Aluminum alloy	Tension Resistence (Kg/mm²)	Expansion (%)	Yeild Strength (Kg/mm²)
1100 (ASTM)*	7.7 - 10.9	35	2.1 - 3.6

* Alternative alloy: 3003 (ASTM)

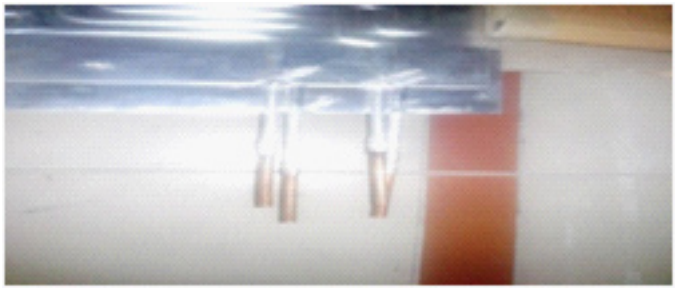
Painting Specification

	Single side Painted	Both sides Painted
Painted Type	Epoxy - Poliester Powder	
Thickness	30 - 60 µ	
Hardness	HB Pencil	
Color	Painted Side: Appliance White Unpainted Side: Flash coating of painting	Appliance White

3.10. Brazing Aluminum to Copper:

Copper tubes are provided to connect to system. First an aluminum tube is brazed to roll bond plate and then a copper tube is crimped to aluminum tube

Photo 7: Aluminum to Copper joining



Final inspection is carried out for any scratches on the surface and the length and width .The circuit on the panel in check for deformations. The sheets are then carefully packed for dispatch.

Photo 8:Final Aluminum Roll bond Evaporators

4 .IN PROCESS REJECTION

Like any other industry, even the management of Annapurna Earcanal Ltd. has encountered some problems. Leaving the raw material untouched for a considerably long period leads to the increase in the hardness of the aluminum sheets. This is called Ageing. Also the dust which gets settled may choke the compressor, if not cleaned properly. Some of the other faults identified, due to which the sheets are rejected are discussed below.(4.1-4.4)

4.1 No Inflation

At the time of inflation, only the inked region is supposed to inflate and the rest of the sheet should be bonded. But, due to some reasons, even the places where bonding isn't supposed to happen, happens. This is called No Inflation (NI).

4.2 Short Length

Sometimes, a part of the aluminum sheet expands lesser than the rest of the sheet. This happens during the rolling process. This variance is called the Short Length (SL). The reasons for this are unknown.

4.3 Cross

In the middle of the circuit, it has been observed that there is a small site where the sheets get bonded and thus oppose the free flow of the refrigerant. This anomaly is called the Cross.

4.4 Poor Bonding

Sometimes, due to some reasons, even the non-inked region gets inflated and leads to irregularity in the circuit design. This phenomenon is called Poor Bonding (PB). It has been observed that this defect occurs repeatedly at certain locations in the circuit in a particular design. Our project as assigned by the works manager is to find the reason behind this phenomenon and a solution to it. We have done our research on the possible processed where the defect must be taking place.

5.2 Thermodynamics of Annealing

Annealing occurs by the diffusion of atoms within a solid material so that the material progresses towards its equilibrium state. Heat is needed to increase the rate of diffusion

Alloy Used	Shear Strength Results	Tensile Strength Results	Pressure Resistance Results	Joint Quality		
				Base Metal Erosion	Gas Porosity	Irregular (Shrinkage) Porosity
88Al/12Si	1	1	2	3	3	1
78Zn/22Al	2	3	3	3	2	3
98Zn/2Al	3	3	2	1	1	2
1 = lowest 3 = highest						

Table 4. Qualitative Rating of Alloy Systems Tested

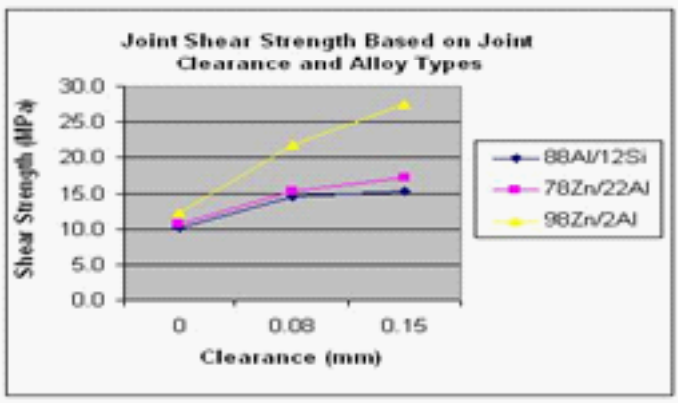


Figure 3. Graph Shear Strength Vs Clearance

Model No.	Chamber Size L × W × H (mm)	Load Capacity (ton)	Heating Power (kw)	Max. Working Temp. (℃)	Temp. Uniformity(℃)
TH-B10	4000*1900*2000	10	300	450	±3
TH-B20	6000*1900*2000	20	600	450	±3
TH-B30	8000*1900*2000	30	840	450	±3
TH-B40	10000*1900*2000	40	1080	450	±3
TH-B50	12000*1900*2000	50	1450	450	±3
TH-B60	13000*1900*2000	60	1800	450	±3
TH-X10	6000*1900*1600	10	400	450	±3
TH-X20	8000*1900*1800	20	650	450	±3
TH-X30	10000*2000*2300	30	900	450	±3
TH-X40	12000*2100*2300	40	1200	450	±3

Conclusion :

1. The aluminum annealing furnace applies to the annealing of finished and semi-finished aluminum sheet or foil.
2. Fast heating: strong air-circulation makes rapid heat-transfer from heater to aluminum coil, providing fast heating.
3. Uniform temperature: when temperature is under 650c, heat transfer is mainly by convection. This aluminum annealing furnace transfers heat from heater to aluminum coil through hot air circulation. Strong air circulation heats both sides of the aluminum coil and makes its inner temperature the same as the external within a short time.
4. Stable quality: blower frequency control device keeps temperature uniformity in the furnace within ±3c, which reduces operational cost by 20%, and annealing cycle by 1/3, compared to the traditional annealing furnace.

Acknowledgement:

1.Annapurna Earcanal Ltd. for showing us the roll bond process in their factory at Patancheruvu.
2.MSME Project "Power Saver: Roll Bond Evaporator for Air conditioner"

References:

1.Ningbo Ningzheng Aluminum Industry Co. ,Ltd.
--A professional factory to bond produce roll evaporator.
2.From the psychometric chart or the enthalpy chart, determine the enthalpy that corresponds with the temperatures.
3.Kokovev, L. S., Kharitonov, V. V. Methods of calculating
Contact heat exchange. I - Heat conduction of Contiguous irregularities; II - Heat conduction of gas Gaps. Journal of Engineering Physics, Russian Translated,1978.

4.Cooper, M. G., Mikic, B. B. and Yovanovich, M., Thermal
Contact conductance. Int. J. Heat Mass Transfer, 1969,
12, 279–300.
5.Laguerre, O., Ben Amara, S., Charrier-Mojtabi, M.C., Lartigue, B.,
Flick, D., 2008. Experimental study of air flow by natural
Convection in a closed cavity: application in a domestic
Refrigerator. J. Food Eng. vol. 85, 547e560
6.Silva, L.W., Melo, C., 1998. Heat Transfer Characterization in Rollbond
Evaporators, MSc. dissertation, Federal University of Santa Catarina, Brazil.