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Partial Cooling of Non-A/c Railway's Coaches using Chemical Solution

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Abstract

The main objective of this research work is to provide partial cooling to the Non-A/c railway's coaches, like sleeper and passenger coaches, for the short distant journey train through the air-duct made in the roof of the coaches. Partial cooling is the process of reducing the temperature of hot air coming to the coaches up to some extent using chemical solution based on simple heat transfer concept. As we know, there is no any cooling system for Non-A/c coaches in the railway, so it is great difficult to travel in these coaches in summer time. This paper describes a simple arrangement, which work on the simple heat transfer process, of a new component including a plastic container having the chemical solution and a hollow coiled pipe of Aluminium which passé through the solution. This arrangement doesn't have any electrical component and it can be fixed easily within air-ducts.

Keywords: *Non-A/c coaches of railway, partial cooling, heat transfer, chemical solution, Air-duct*

1. Introduction

The project works deals with the partial cooling of Non-A/c coaches. At present time, there is no any cooling arrangement for Non-A/c coaches. Now as we know, the temperature of some region in India is to high around 35-45 ^{o}C during summer time and this hot air not only enters from doors and windows but also through the air-duct, provided in the roof of coaches, at high temperature with high velocity due to simple drag force during the motion of train. As a result of this the temperature of the coaches increased drastically and hence it is too difficult to travel in Non-A/c coaches. Same time, it is not possible to provide arrangement like A/c coaches since it will again raise the power consumption which can affects the fare cost for the common people. So, it is need to provide a simple arrangement which don't have any electric component to raise the power consumption and provide slightly cooling-conditioning air to the cabin of the coaches through air-ducts. Now, this paper describe about a simple arrangement, without any electrical component, which can be easily fitted in the air-ducts for providing slightly cooling air during the motion of train. Since it doesn't have any electrical component so there is no any chance power consumption and also it works on the simple concept of heat transfer process. Here in this arrangement, the main thing is the selection of correct materials. This arrangement consists of container of thermo-plastic having an aqueous chemical solution of NH_4Cl and a coiled pipe of aluminium passes through the solution. The proposed arrangement would be having a container filled with chemical solution having coiled aluminium pipe immersed in it.The set up will be placed in the air duct provided in the roof of the coaches.The chemical solution is a mixture of water and ammonium chloride having a temperature of about 15 degree celcius.So,the cool chemical solution and the immersed pipe would be the elements of heat transfer process.The various elements used for the proposed components are:

1.1 Thermo-Setting Plastics

A thermosetting plastic, also known as a thermoset, is polymer material that irreversibly cures. It can't change again and again by applying heat. The cure may be done through heat (generally above 200 °C (392 °F)), through a chemical reaction (two-part epoxy, for example), or irradiation such as electron beam processing.

Properties

Thermoset materials are generally stronger than thermoplastic materials due to this three dimensional network of bonds (cross-linking), and are also better suited to high-temperature applications up to the decomposition temperature.

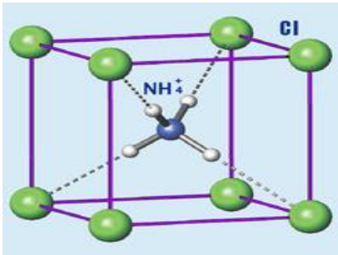
1.2 Ammonium Chloride

Ammonium chloride, an inorganic compound with the formula NH_4Cl, is a white crystalline salt, highly soluble in water. Solutions of ammonium chloride are mildly acidic. Sal ammoniac is a name of the natural, mineralogical form of ammonium chloride. The mineral is commonly formed on burning coal dumps, due to condensation of coal-derived gases. It is also found around some types of volcanic vent. It is used as a flavoring agent in some types of liquorices. It is the product from there action of hydrochloric acid and ammonia. Ammonium chloride is used to produce low temperatures in cooling baths. Ammonium chloride solutions with ammonia are used as buffer solution. It is very slightly reactive to aluminium. This can prevented if proper buffer solution is used.

Properties

Properties	
Molecular formula	NH_4Cl
Molar mass	53.491 g/mol
Appearance	White solid hygroscopic
Odor	Odourless
Density	1.5274 g/cm^3
Melting point	338 °C (decomposes) Boiling pt = 520
Solubility in water	297 g/L (0 °C) 372 g/L (20 °C) 773 g/L (100 °C)
Solubility in alcohol	6 g/L (19 °C)
Acidity (pK_a)	9.245
Refractive index (n_D)	1.642
Thermo chemistry	
Std enthalpy of formation $\Delta_f H^\circ_{298}$	−314.55 kJ/mol
Standard molar entropy S°_{298}	94.85 J K^{-1} mol^{-1}

Chemical Structure:



When Ammonium chloride reacts with water at room temperature it produce ammonium hydroxide which is endothermic in nature.

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$NH_4Cl + H_2O = NH_4OH + HCl - \Delta$

Solubility of Ammonium Chloride in Water

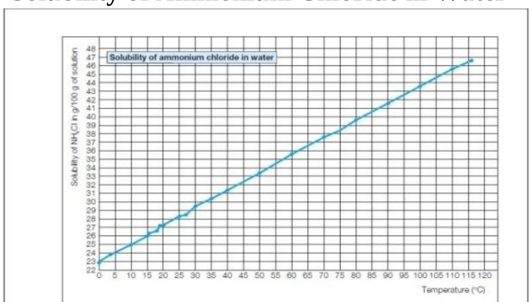


Fig. 1 Solubility of ammonium chloride in water

1.3 Aluminium

Aluminium (or aluminum) is a chemical element in the boron group with symbol Al and atomic number 13. It is silvery white, and it is not soluble in water under normal circumstances. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals.

Physical Properties

Aluminium is a relatively soft, durable, lightweight, ductile and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A fresh film of aluminium serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa in aircraft industries. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Aluminium atoms are arranged in a face-centered cubic (fcc) structure. Aluminium has stacking-fault energy of approximately 200 MJ/m^2.

Chemical Properties

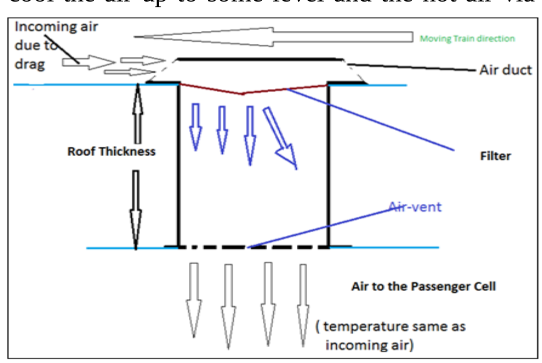
Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is also often greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

Health Concerns

Despite its natural abundance, aluminium has no known function in biology. It is remarkably nontoxic, aluminium sulfate having an LD50 of 6207 mg/kg (oral, mouse), which corresponds to 500 grams for a 80 kg person. Despite the extremely low acute toxicity, the health effects of aluminium are of interest in view of the widespread occurrence of the element in the environment and in commerce.

2. EXISTING ARRANGEMENT

Presently, there is no such cooling arrangement for these Non-A/c coaches to cool the air, hence the ambient air that enters the cabin is quite hot alike the air that enters through the windows and door panel. In the summer season, the hot air not only enters through the doors and windows but also through the air-ducts due to drag force during the motion of train. As a result of which, the hot air heats up the atmosphere inside the cabin. At present time, the air-ducts act simply as a passes for the entering air from outside to inside the cabin. There is no any arrangement to cool the air up to some level and the hot air via



the air-ducts mixed with air available inside cabin which already at high temperature.

Pictorial diagram of existing arrangement within the air-duct

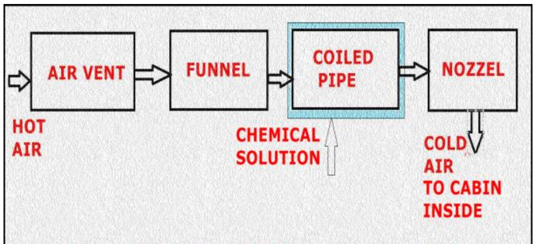


FIG: BLOCK DIAGRAM OF PARTIAL COOLING OF NON-A/C COACHES

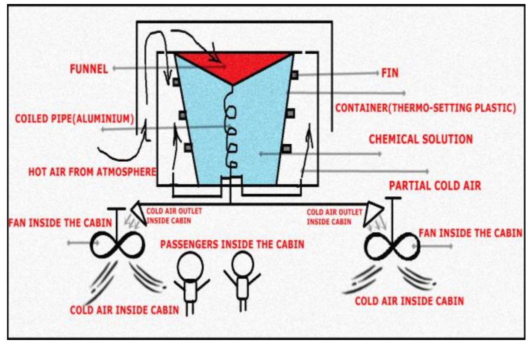
3. Proposed arrangement

The proposed arrangement, as already mentioned, is consists of a thermo-plastic container having a chemical solution of Ammonium chloride through which a coiled pipe of Aluminium is allowed to passed. The arrangement which works on the principle of Heat Transfer concept, can be easily fixed within the air-ducts provided in the roof of the coaches.

3.1 Working of Proposed arrangement

The chemical solution is a mixture of water and ammonium chloride having a temperature of about 15 degree celcius.So,the cool chemical solution and the immersed pipe would be the elements of heat transfer process. Now, during the motion of train air will be draged to the air-duct and will be allowed to passed through the coiled pipe. When the draged air will pass through the coil, since aluminium is the good conductor of heat and the solution arround it is endothermic in nature, so it will absorbe the heat from the hot draged air according to the heat transfer concept. Now the air which will enter to the cabine via coiled pipe is some what cooler than it before condition and then it will trarsfer to the fans via nozzle which further espred to the cabine. Now this cooler air will mix with the cabine inside air and make it again some what cooler than before. As a result of this there is a reduction in the overall tempreture inside the cabine.

Pictorial view of the proposed arrangement



4. Calculations and results

Experimental Observations: in leboretory condition at room temperature 28 °C

Solubility ratio- H_2O: NH_4Cl = 10:3
Interval time is 5 minutes for each observation.

Table 1. Behaviour of solution of ammonium chloride with the increase in temperature

Initial temperature of the water bath (°C)	Initial Temperature of the Solution(°C)	Final Temp. of the Solution(°C)
40	14	22
38	22	28
39	28	34
39	34	36

The chemical solution i.e., water and ammonium chloride is poured into a glass beaker and keep upon heating bowl containing water at normal room temperature. Gradually and constantly, the water in the bowl is heated with the chemical solution in beaker with it. This experiment is executed to see and note the temperature changes in the chemical solution as the water temperature in the bowl changes for constant heating.

Table 2: Temperature of aqueous solution at different solubility level

Water (ml)	Amonium chloride (gm)	Initial temperature of solution (°C)
10	3	16
10	4	14
10	5	13

This experiment is conducted to see what amount of low temperature can be obtained for the solution by mixing water and ammonium chloride together with various ratios shown above.

Table 3: Initial and final temperatue of the air after passing through the coiled pipe within the solution

Initial temperature of air (℃)	Final temperature of air (℃)
40	29
38	27
39	27

4.1 Calculation Of Work Done:

Considering, the system to be following a Polytropic process as it expands through out the pipe. The initial temperature and final temperature is taken from the above observation.
The process follows the laws of PV^n = constant
Where n= polytropic index = 1.33
From the First law of Thermodynamics

$$Q = W + \Delta U \dots\dots\dots (1)$$

Where Q= Amount of heat transfer (KJ)
W = Work done (KJ) ΔU = Internal energy (KJ / Kg)
From equation (1),

$$Q - W = \Delta U$$

Now,

$$W = m \times \frac{R(\mathrm{T1} - \mathrm{T2})}{(n-1)}$$

Where, T_1 = Inlet temperature
T_2 = Out temperature
R = Universal gas constant = 0.297 KJ / Kg K

for unit mass,

$$W = 1\times\frac{0.297(44-29)}{(1.33-1)} = 13.5 \text{ KJ}$$

4.2 Amount Of Heat Transfer

$$Q = W \times \frac{(\gamma - n)}{(\gamma - 1)}$$

$$= 13.5 \times\frac{(1.41-1.33)}{(1.41-1)} = 2.63 \text{ KJ}$$

Therefore, ΔU= (2.63 – 13.5) KJ = -10.87 KJ

Negative sign indicates that there is a loss of energy as it(air) losses it's heat energy to the solution provided.

4.3 Calculation Of C.O.P

As the solution providing refrigent effect since it is used to remove heat form cold system.
Therefore, COP of the system is given by,

$$C.O.\mathrm{Pref} = \frac{Q_R}{W}$$

$$= \frac{Q_R}{Q_S - Q_R} = \frac{T_l}{T_h - T_l} = \frac{29}{44-29} = 1.33$$

4.4 Calculation of heat transfer co-efficient

As we know $\mathrm{Nu} = \frac{hl}{K}$,

therefore , $\mathrm{h} = \frac{Nu \times K}{l}$

Where Nu = Nusselt number,
h = Co-efficient of heat transfer
K = Thermal conductivity (W/mK)
l = length of coiled pipe (m);
Now, as we have inlet temperature of air T_w = 44℃
And outlet temp. to the cabine $T_\infty = 29\ ^oC$

Therefore, avg fuild temp. = $\frac{44+29}{2} = 36.5\ ^oC$,

Now, properties of fluid at 36.5 ℃;
Density $\rho = 1.41$ Kg/m^3,
Thermal conductivity k = 0.0271 W/mk,
Kinematic viscosity $v = 17.02 \times 10^{-6}$ N-s/m^2
And, $\beta = \frac{1}{(36.5+273)}$ K^{-1} $= 3.23 \times 10^{-3}$ K^{-1},

And Grashof's number, Gr = $\frac{g \times \beta \times l^3 \times \Delta T}{v^2}$
$= \frac{9.81 \times 3.23 \times 10^{-3} \times 0.18^3 \times (44-29)}{(17.02 \times 10^{-6})^2} = 4.467 \times 10^6$.

Now, Gr×Pr = $4.467 \times 10^6 \times 0.701 = 3.131 \times 10^6$
Since, Gr×Pr $\leq 10^9$, hence it is a Laminar in nature.
Therefore, Nu = $0.59 \times (Gr \times Pr)^{0.25}$

Nu = $0.59\,(3.131 \times 10^6)^{0.25} = 28.824$.

Again, we know Nu = $\frac{hl}{K}$
Therefore, h= $\frac{Nu \times K}{l}$
$= \frac{28.824 \times 0.0271}{0.18} = 4.33$ W/m^2 k

5. Conclusion and Future scope

The proposed arrangement has several benefits over the typical arrangement available in present day Non-A/C Coaches. The present day arrangement allows the hot air drags inside the cabin while the train runs with certain velocity. The air is not processed and its temperature remains quite hot. The proposed arrangement avails the hot air that drags inside through vent. The hot air is processed through coiled pipe surrounded by cold chemical solution. In the process, the air turns colder and the passengers inside receive somewhat colder air. The benefit of using this proposed arrangement is that, the passenger cabin would able to receive partially cold air rather than hot air.

6. Acknowledgments

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