Design of

Forced air ventilation system for railway sleeper coach

Submitted by

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Above all my acknowledgement to my parents who have always supported me throughout my life.

Declaration

I declare that this written submission represents my idea in my own words and where other ideas or words have been included, I have adequately selected and referred the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not misinterpreted or fabricated or falsified any idea / data / facts / sources in my submission. I understand that any violation of the above will cause for disciplinary action by the institute and can also evoke penal action from the sources which have just not properly sighted or from whom proper permission has not been taken when needed.

Signature

Roll No.

Name

Date

Approval

Industrial Design Project 3

" "Design of a forced air ventilation system in Sleeper coaches for Indian railways".

By Siddhartha Mukherjee

M.Des, Industrual Design Batch 2012-14 is approved as a partial fulfillment of requirement of Post Graduate degree in Industrial Design.

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Abstract

Indian railway sleeper coaches have always been dependant on the windows for natural ventilation. Be it hot or cold or raining outside, closing the windows was never a feasible option. It only meant sacrificing on the passenger's comfort and the proper ventilation. The open windows also invites in loads of dust at high speeds and passengers are often prone to theft of their belongings due to open windows. The project thus is carried out from a proposal by the Indian railways for developing a forced air ventilation system for a sleeper coach thus eliminating the need for openable windows , and depending on them for ventilation. The project also aims to improve the overall hygiene and cleanliness of the coach.

Contents

Introduction

The Indian Railways

The history of rail transport in India began in the mid-nineteenth century. The motive behind devloping railway services in India came from London. Till 1850s there was not a single kilometre of railway track in India. The first train that plyed on Indian tracks was introduced between Bombay (now Mumbai) and Thane in 1853. From 1857 onwards a British engineer named Robert Maitland Brereton was assigned the task of the expansion of the railway programme. He worked on the construction of the Bombay to Calcutta (now Kolkata) railway network which later formed the backbone of the The Indian railways is an Indian state-owned enterprise, owned and operated by the Government of India under the Ministry of railways. Spanning over 65000 Km of track route and more than 7500 railway stations. It is the fourth largest railway network in the world behind the United States of America, China and Russia. (Indian Railways, wikipedia n.d.)

Of the total railway route, 16,001 Kms are electrified. The railways have 8000 locomotives, 50,000 coaching vehicles, 222,147 freight wagons and a humongous work force of 1.54 million people. Indian Railways runs around 11,000 trains everyday, of which 7,000 are passenger trains which includes the long distance trains as well as the dedicated suburban railway network in select cities such as Mumbai, Kolkata, Chennai, Delhi and Bangalore and Lucknow. Hyderabad and Pune share their sub urban railway tracks with long distance trains.

Inspite of this Indian rail infrastructure suffers from chronic under-investment which cripples its potential for freight movement and upgradation. Indian railways need extensive modernisation, improvement of safety and modernisation of the rolling stock with attention to passenger comfort to meet the needs of a rapidly growing economy. (Ankit Rastogi 2013)

Passenger

carrying fleet

2.1 The mushrooming population

Over time the passenger traffic has risen leaps and bounds from 1284 million in 1950-51 to 5112 million in 2002 - 2003. Increase in India's population and demand for work, supplies etc has contributed heavily to the railway usage. The railways have contributed in connecting all the extremities and the corners of the country into one unified network. The inter connectivity among different trains thus require an enormous amounts of long distance trains which can support the transit of thousands of people daily. (Ankit Rastogi 2013)

With average speeds of 90Km/hr the long distance trains (Express trains) can take anywhere from 24 hrs to 82 hrs to reach their destination.

2.2 Passenger classes in trains

There are 3 reserved passenger carrying classes currently in the long distance trains namely the Sleeper class, 1st A.C, 2 tier A.C sleeper and the 3 tier A.C sleeper. Chair Cars are not in use in trains where journeys exceed 10 to 12 hrs. Apart from the reserved classes there are 2 to 4 coaches attached for unreserved passengers.

1853 First train runs between Bombay and Thane

1857 Expansion of the Bombay Kolkata corridor

1867 Central India gets connected. Allahabad-Jabalpur link started

1875 British invest 95 million pounds for expansion of railways throughout India.

1880 Bombay, Kolkata and Madras gets connected to parts of Central India. Track length of 14,500 Km established.

1895 The first locomotive works set up.

1900 The Great Indian Peninsular railway (GIPR), the precursor to Indian railways becomes a govt. owned company

1905 The first railway board constituted.

1907 Electric locomotive makes the first appearance.

1920 Railway network expanded to 61,220 Km

1920-1929 marks the period of maximum economic development

1946 Indian Railways becomes the sole proprietor for running railways in India.

1950 Early variants of AC coaches appear.

1955 The Integral coach factory (ICF) is established. Integral coaches replace the older wooden bodied coaches

1980 Cushioned seats gradually replace the older wooden plank seats from the sleeper class

(Indian Railways, wikipedia n.d.)

Land marks

in the history of Indian Railways

1st A.C

The First class A.C is the most expensive class where the fares are on par with airlines. Bedding is included in the fare. These coaches are single or two in number in select trains of popular routes and carry 18 passengers in the old ICF (Integral Coach Factory) coaches and 24 passengers in the newer LHB coaches (present in some Rajdhanis and Durontos). The coaches are carpeted and have privacy features like personal coupes.

2 tier A.C sleeper

Air conditioned coaches with berths for sleeping, wider seats, ample leg room, curtains and individual reading lamps. Berths are arranged in two tiers in bays of six. Four berths along the width of the coach in the aisles and two along the gangway. Bedding included in the fare. Curtains offered for privacy. It can carry 46 passengers in case of the ICF coaches and 52 in the LHB coaches.

3 tier A.C sleeper

Air conditioned coaches with sleeping berths. Berths are arranged in a similar fashion to the 2 tier coaches but has six berths arranged width wise in the aisles (3 tier arrangement) and two along the gangway. They are usually less appointed compared to the other air conditioned classes, usually no reading lights although curtains are provided. Bedding included in the fare. It carries 64 passengers in the ICF coaches and 72 is the LHB coaches.

Sleeper class

the backbone of the system and the project

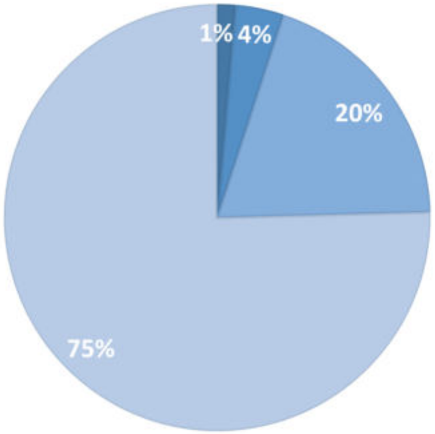
3.1 The most preferred one

Although the most preferred class for travel, the sleeper class is certainly not the most comfortable way to travel. Most preferred by people because of the cheaper tickets compared to the least expensive air conditioned class. Sleeper class fares are almost one third of the fare of the 3 tier AC sleeper (it's richer sibling). The arrangement of the berths is in the same format, six seats width wise in the aisle and two seats along the gangway. Bedding is not provided and there is no provision for privacy for the passengers. Sleeper class can be quite crowded (although in theory all berths must be reserved, so it can't get overcrowded) because of locals who use the class to commute daily where suburban trains are not available as well as the waitlisted passengers without a confirmed ticket.

3.2 Passenger facilities and comfort

The sleeper class is the basic choice which actually gives the best view of a countryside compared to the most AC coaches with sealed windows. It has openable windows as ventilation is provided solely by them and has ceiling fans to save the passengers during hot sumers. Monsoons can be best and the worst too. The rain and the flowing wind can be the most comfortable thing along with the spectacular views outside. But unfortunately if it's raining too hard the windows have to be kept shut and it can get quite stuffy inside as well as dark inside. During winters the nights get too chilly as the trains cross a lot of climatic zones in India .

(Right) The seating/sleeping layout in a typical sleeper class coach with six berths widthwise along the aisle in a tier of three and two seats length wise along the gangway in a tier of two.



Percentage calculation of sleeper class passengers in an express train of 24 coaches.

1st A.C 1 no. x 18 (passengers) = 18 (1%)

2 tier A.C sleeper 1 no. x 48 = 48 (4%)

3 tier A.C sleeper 4 nos. x 64 = 256 (20 %)

Sleeper Class 14 nos. x 72 = 988 (75%)

3.3 Passenger inconveniences with the existing system

Apart from the temparature problems inside the train depending solely on the windows for ventilation has its own problems.

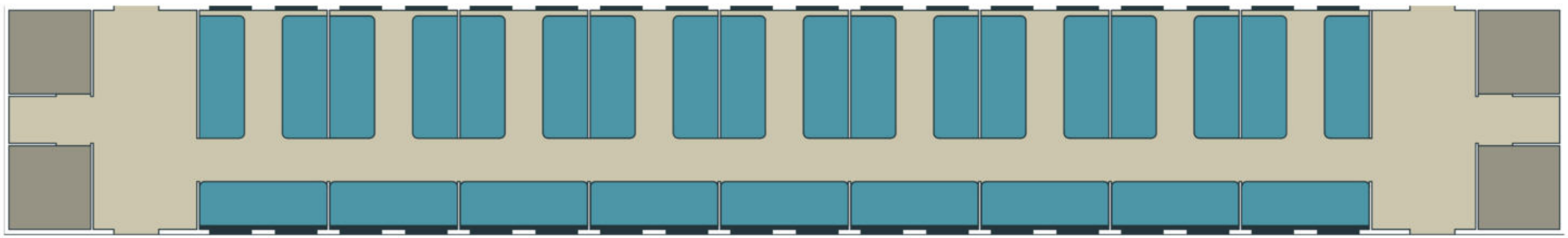
The train at high sppeds invites in a lot of dust which affects the cleanliness of the interiors badly. Frankly speaking interiors of a sleeper class always look dirty even though they get washed regularly at the carsheds. The dust from outside accumulate on the berths and with people repeatedly sleeping on it, the dust adheres well to the berths due to body sweat lending it a dirty sticky feel.

During rains the louvered part of the window generally doesn't help and the glass panel has to be pulled down. With no ample room for ventilation the interior becomes stuffy.

The toilets are grim, unpleasant odours constantly waft throughout the compartment whether the train is moving or stationary.

Since there are no zones defined in a sleeper coach any number of people tend to get in and try to manage to sit wherever they can. Eunuchs and beggars too find their daily source of income in the sleeper coaches.

There is a tendency of people to throw stuff like cow dung, stones or water balloons (during holi) onto moving trains.



Passenger seating layout in a sleeper class coach

Design
Opportunities

4.1 What to change

Over the period of time Indian railways has expanded greatly both in terms of track length and train services making it the most preferred transit system over other means. Although low fare airlines were introduced around 2008 and 2009. Nothing matches the dependability of a well organized system spread thousands of Kilometres across connecting almost every corner of the nation to another. In its 150 years of service the railways has both flourished and seen tough times only to redesign and innovate for a leap ahead.

Passenger comfort therefore becomes an integral part which needs to be looked in and improved bit by bit.

The railways has thus offered interest in resolving the issues mentioned earlier for the sleeper coaches in long distance travel by looking for a ventilation system that becomes the baby steps for one aspect of passenger comfort.

Though a lot of new air conditioned trains such Duronto, Garib Rath etc are started, there has been negligience from the authority and the passenger point of view to look into ways which can improve how almost 80% population in a train travels.

(Right). The sleeper class interiors
Image courtesy. . http://waterov.files.wordpress.com/2011/08/100_2261.jpg

(Above). Small children like to sit near the windows which are potential spitoons for the paan and gutkha chewers. A potential medium for spreading diseases.
Image courtesy. . http://www.rashayousif.com/wp-content/uploads/galleries/post-209/c36-SleeperClass-6.jpg

(Above). The toilets are not partitioned properly from the passenger cabin. Since they are generally unclean, obnoxious odours waft constantly.
Image courtesy. . http://www.dreamtravellive.com

Design brief

To design the most apropriate solution for providing artificial ventilation in the sleeper coaches of Indian railways which provides passenger comfort and an overall hygienic environment.

5.1 Factors behind the design brief

The design challenge apart from requiring technical intervention requires the understanding of usability and passenger comfort as well as a high service life and easier maintenance

5.2 Primary and secondary users

The Primary user group comprises of the passengers of the train who will be constantly exposed to the created environment throughout the journey. Considerations for proper air flow , prevention of rain water seepage (due to artificial intervention) need to be accounted the most. The primary users won't be interacting directly with the product but should have some provision to tweak it as per their need.

The secondary users are the maintenance staff who will have the responsibility of cleaning the system and ensure proper maintenance over the ourse of the train journey. It should be thus easy for them to comprehend and understand it for it's proper functioning

5.3 Design wishlist

What needs to be achieved and what guides the design brief are highlighted aside.

Rethinking on the ventilation system in a sleeper class coach, which over the years was dependent on the natural airflow through windows.

Opportunity to create hygienic ambient conditions free from dust and pollutants as well as keeping obnoxious odours from the toilet at bay

Reducing the ambient noise level

Ease of maintenance in limited time as the train halts or is in the yard

Image courtesy.
http://1.bp.blogspot.com/_eXLI2mTF63M/S50_6LchkCI/AAAAAAAAAW4/7J4NiHwHYMo/s1600-h/11.JPG

Rolling stock

of Indian Railways

Passenger railway coaches are generally categorized based on their manufacturer or on their primary power source for handling electrical fittings inside the coach.

6.1 Based on the manufacturer

ICF COACHES

The older rakes of the Broad gauge (1676mm) of the Indian railways are manufactured in India in the Integral coach factory (ICF) in Perambur, Tamil Nadu since 1952 as well as in Rail coach factory (RCF) Kapurthala, Punjab. These coaches can be identified by the distinguishable blue and white livery. (The Indian Railways fan club n.d.)

LHB COACHES

LHB coaches are passenger compartments of Indian railways that have been developed by Linke Hofmann Busch of Germany 2 (remnamed Alstom LHB GmbH in 1998 after the takeover by Alstom) and currently produced by the Rail coach factory in Kapurthala. They are in use since 2000 on the Indian Broad gauge (1676mm) network. Initially 24 air conditioned coaches were imported from Germany for use in the Shatabdi Express, after which the RCF started manufacturing after technology transfer.

The coaches are designed for an operating speed ranging from 160 Km/h to 200 Km/h. However test runs were conducted upto a speed of 180 Km/h.. Measuring at 23.54 m length and 3.24 m width, they are bigger compared to the conventional ICF rakes and thus can carry more passengers. Advanced braking and pneumatic suspension ensures better safety and passenger comfort. The noise levels in a LHB coach is lesser compared to the ICF coach 60 decibels versus 100 decibels. (LHB Coaches n.d.)

(Right). Modernized LHB rake being used in Shatabdi Express
Image courtesy.
http://1.bp.blogspot.com/_eXLI2mTF63M/S50_6LchkCI/AAAAAAAAAW4/7J4NiHwHYMo/s1600-h/11.JPG


वातानुकूलित कुर्सी यान
AC CHAIR CAR


शयनयान
SLEEPER
24-17
आपातकालीन खिड़की
EMERGENCY WINDOW

The RCF began to manufacture other variants of LHB design like the A.C first class, A.C 2-tier sleeper, A.C 3-tier sleeper, bot buffet (pantry) car etc., from 2001 to 2002. RCF rolled out the first rake in December 2002 which was used in Mumbai-New Delhi Rajdhani Express in December 2003. As of March 2011, 997 LHB coaches were manufactured by the RCF. The premier trains such as Rajdhani, Shatabdi and some of the Durontos got the privilege for using these rakes.

Indian railways have decided to replace the conventional ICF made sleeper coaches with the modern ICF coaches by the end of 2016. Trains such as Poorva express and Purushottam express have upgraded to RCF made non air conditioned LHB coaches. (LHB Coaches n.d.)

(Above). RCF made LHB sleeper coaches are in use currently in few trains such as Howrah-New Delhi Poorva express and the Purushottam express.
Image courtesy. http://farm9.staticflickr.com/8464/8138054690_c065674b70_h.jpg

(Left). The existing rake of the ICF coaches majorly used in every long distance train will be phased out by the end of 2016
Image courtesy. . http://www.makingdifferent.com/wp-content/uploads/2013/08/How-to-Make-Train-Reservation-In-India.jpg

6.2 Based on the Power supply generator

SG COACHES

SG stands for selg generating. Power supply demand for electrical equipment as well as air conditioning is met from axle driven transom mounted brushless alternator which is rated for 110 V D.C supply.

At slow speeds and during halts, the power requirement is met from 110V lead acid batteries mounted on the underframe of the coach. Generally most of the ICF coaches used in trains except Rajdhani, Shatabdi or Duronto are SG coaches. The new LHB sleeper rakes are SG coaches as well.

EOG COACHES

EOG or end off generator coaches are airconditioned coaches used in trains such as Rajdhani, Shatabdi and some Durontos. They are available in the ICF based model of coaches as well as the LHB model of coaches.

These coaches draw their power from the diesel generating seta carried in coaches put in the front and/or rear of the rake.

The generators function at 415/750V, 3 phase, 50 Hz AC supply.

Power is distributed throughout the entire rake and thus to each coach through two sets of 3 phase 415/750 V feeders. Each coach is provided with control, changeover arrangement on a control panel. (The Indian Railways fan club n.d.)

(Right). EOG coaches in LHB and ICF Rake showh alongwith the generator cars.
Image sources (shown clockwise from top)
http://upload.wikimedia.org/wikipedia/commons/1/14/Mysore_Shatabdi_LHB_coaches_at_Mysore_Station_(1).JPG

http://4.bp.blogspot.com/--6QGQ0dYF6so/UhjXwRrXAUI/AAAAAAAAB_0/Cg1r8mj2KNg/s1600/DSC09507.JP

http://1.bp.blogspot.com/_eXLI2mTF63M/S50_6LchkCI/AAAAAAAAAW4/7J4NiHwHYMo/s1600-h/11.JPG

http://farm9.staticflickr.com/8464/8138054690_c065674b70_h.jpg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VADODARA
RAJKOT


BRAKE LUGGAGE
& GENERATOR CAR

Exploring

technologies for ventilation systems

7.1 Mechanical ventilation system

Broadly speaking mechanical ventilation stands for forcing air in or out of a chamber or duct by means of a fan generally operated by electricity.

If well designed, installed and maintained, there are a number of advantages to a mechanical system.

Mechanical ventilation are considered to be reliable as they constantly supply a same rate of airflow regardless of the impacts of variable wind and ambient temperature.

Filtration systems can be installed in mechanical ventilation so that harmful microorganisms, particulates, gases, odours and vapours can be removed.

The airflow path can often be controlled.

Mechanical ventilation can work everywhere when electricity is available.

7.1.1 Extract ventilation system

Exhaust ventilation systems work by depressurizing the chamber. By reducing the inside air pressure below the outdoor air pressure, they extract indoor air from a chamber while make-up air infiltrates through leaks in the body shell and through intentional, passive vents.

PROS

They are relatively simple and inexpensive to install. Typically, an exhaust ventilation system is composed of a single fan connected to a centrally located exhaust point in the chamber.

CONS

Extract ventilation system is most suited in cold climates. In climates with warm humid summers, depressurization can draw moist air into wall cavities where it may condense and cause moisture damage.(U.S Dept. of energy n.d.)

7.1.2 Supply ventilation system

Supply ventilation of forced air ventilation systems work by pressurizing the chamber. The system uses a fan to force air into the chamber while air inside leaks out of the chamber through intentional vents.
A typical supply ventilation system has a fan and duct system that introduces fresh air into the chamber .
This system allow better control of the air that enters the confine than do exhaust ventilation system..

PROS

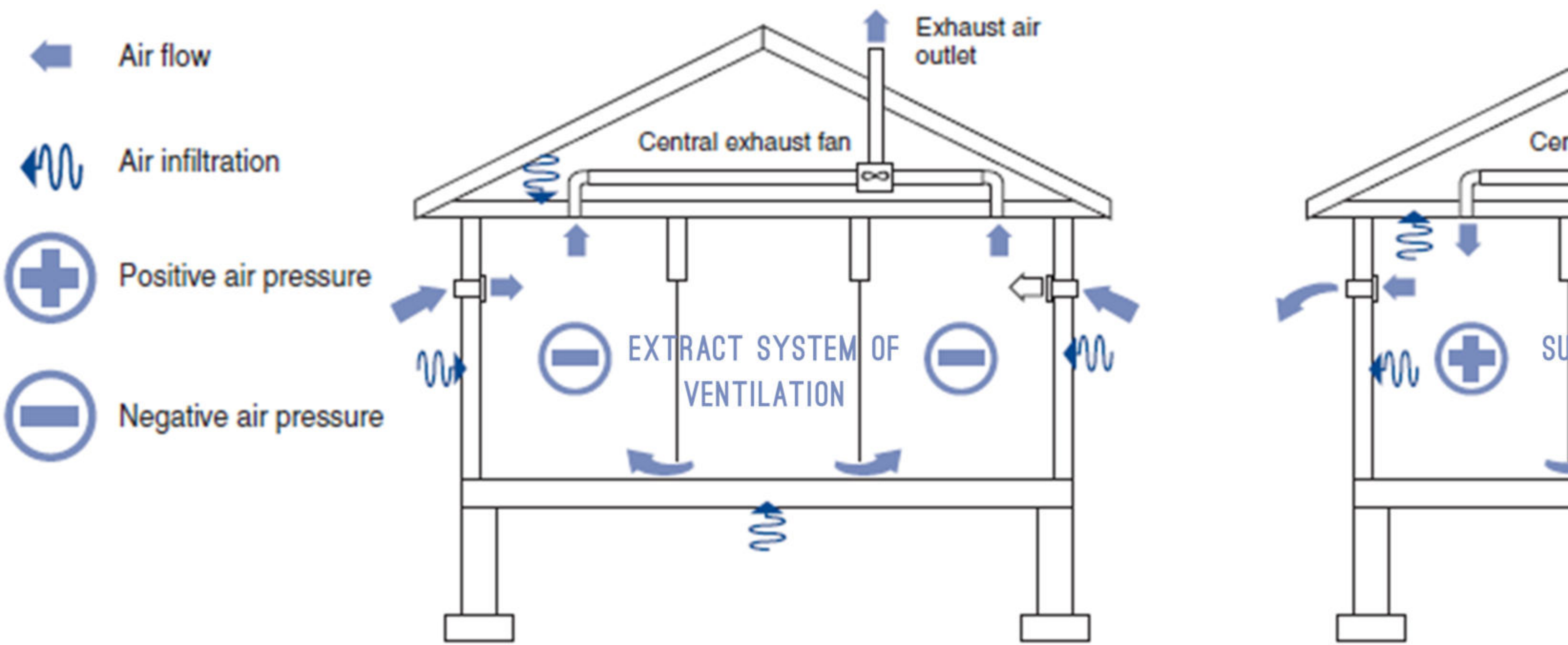
Supply ventilation also allow outdoor air introduced into the confine to be filtered to remove dust and other pollutants from outside and can be dehumidified for humidity control.

This system is well suited for hot or mixed climates.

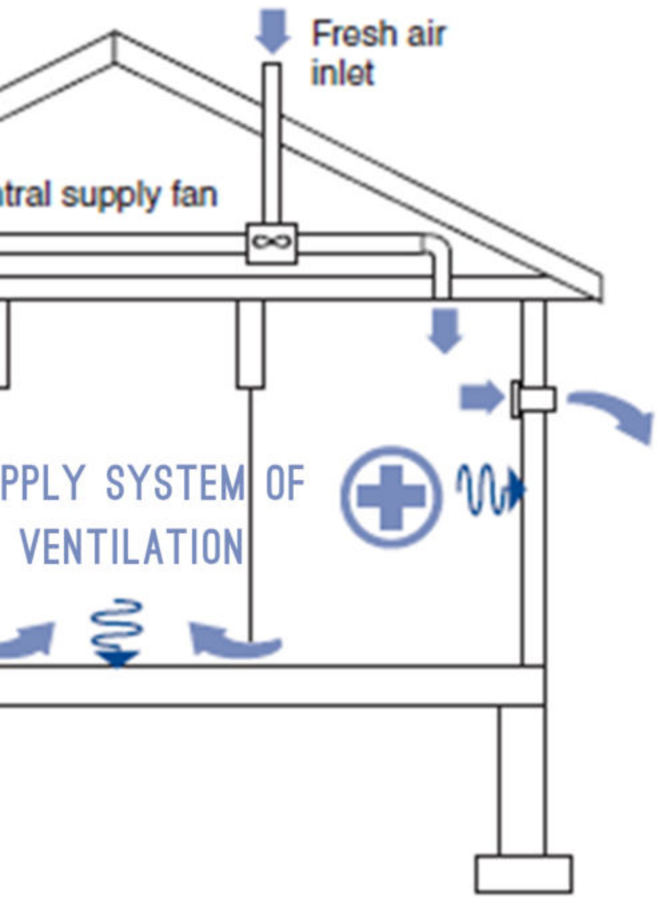
7.1.3 Balanced ventilation system

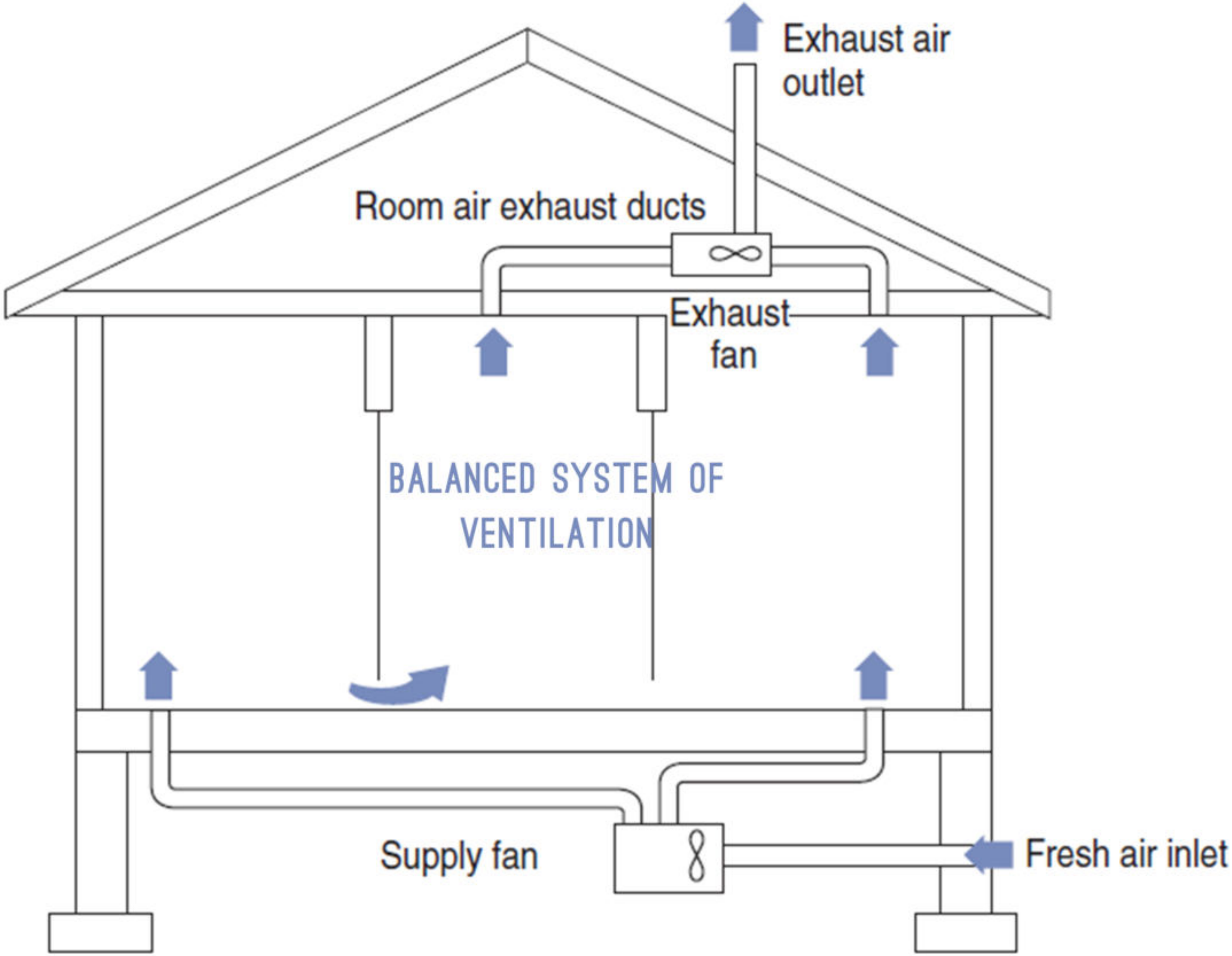
Balanced ventilation systems neither pressurize nor depressurize a chamber if properly designed and installed. Rather they introduce and exhaust approximately equal quantities of fresh outside air and polluted inside air respectively.
This system is suitable for all climates.
This system usually has two fans and two duct systems and facilitates good distribution of fresh air by placing supply and exhaust vents in appropriate places.(U.S Dept. of energy n.d.)

CENTRAL VENTILATION STRATEGIES



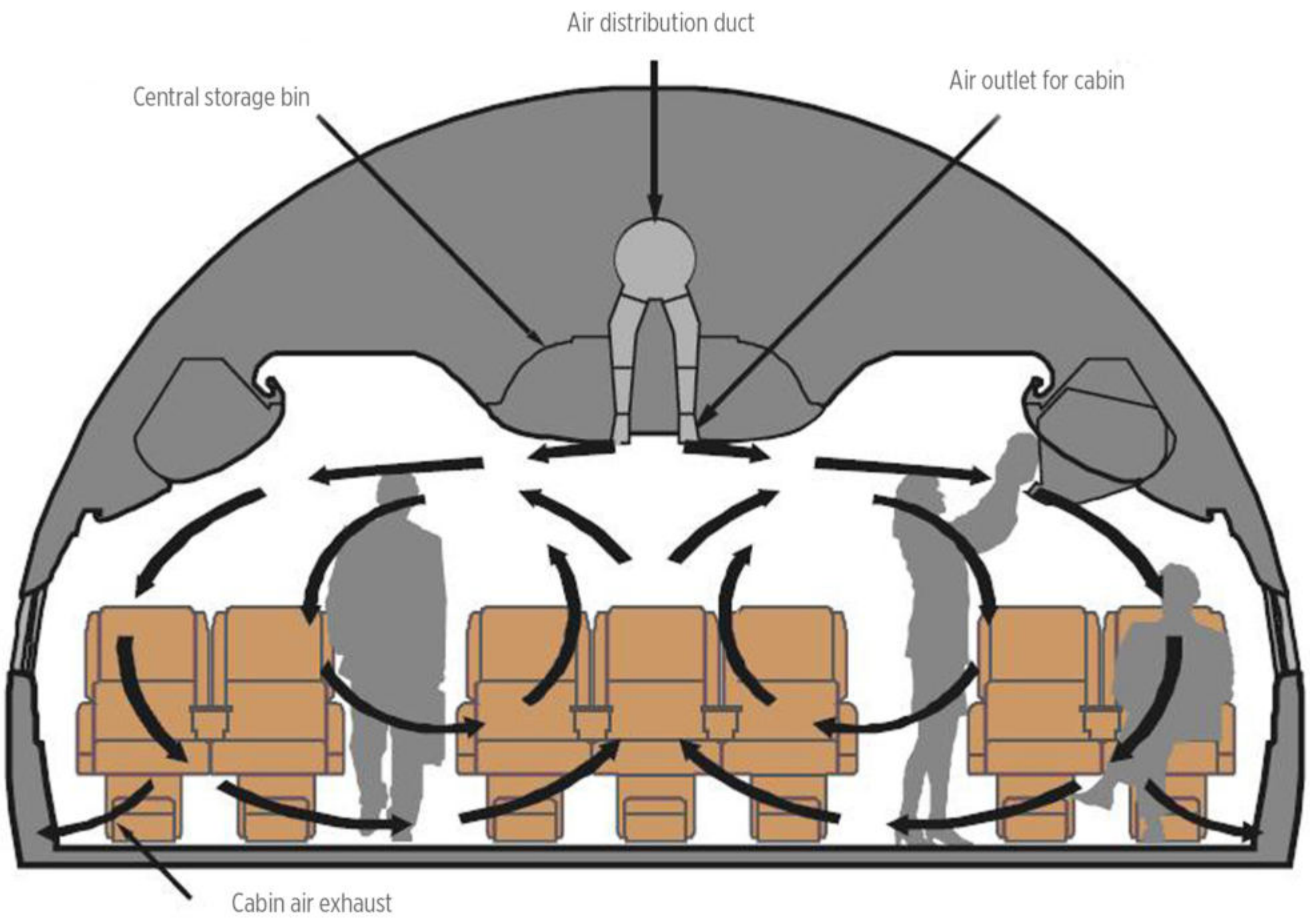
(U.S Dept. of energy n.d.)


Fresh air
inlet
tral supply fan
PPLY SYSTEM OF
VENTILATION


Exhaust air
outlet
Room air exhaust ducts
Exhaust
fan
BALANCED SYSTEM OF
VENTILATION
Supply fan
Fresh air inlet

7.2 Ventilaton in airplanes

Airliners obtain clean compressed air from the engines and use this for air conditioning, ventilation and pressurization.
The air is taken in through the jet engines and after bringing it to a suitable temperature it is circulated in the cabin. Beneath the seats there are exit valves for the air which leaves the cabin and mixed with more fresh air it is recirculated back into the cabin. In general it is 50% outside air sucked by the plane's engine and 50% re circulated air.

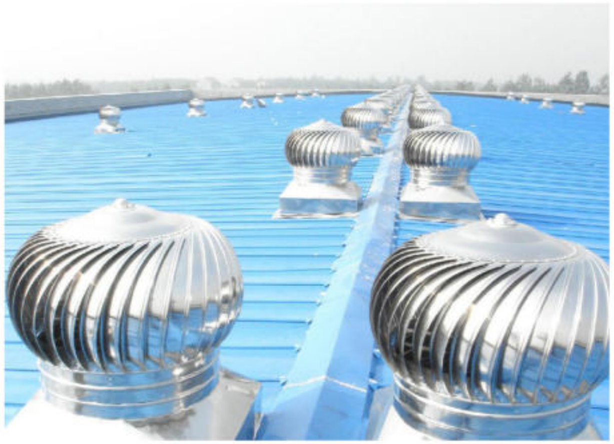


(Above). Typical air circulation inside the passenger cabin of an airplane
http://i.stack.imgur.com/mL3OS.png

7.3 Components for ventilation systems

EXTRACTORS

Roof Extractors are motor driven fan unit having an aluminium alloy impeller, aerofoil section blades and mostly placed on the roofs of houses, warehouses or other buildings to suck the foul air in the chamber and replenish it with fresh air from intentional passive vents on the walls or windows.



(Above). Roof extractors lined along a roof http://img.diytrade.com/cdimg/983286/10835474/0/1256267465.jpg

(Above). Axial fans http://4.bp.blogspot.com/--rI7xfZDEE2A/UQIXFdu0vRI/AAAAAAAAADQ/kGYE-H9oJoA/s1600/AS+FAN.pn

FANS

Fans form the backbone of ta forced air ventilation system, they are used to regulate a constant flow throughout a ductwork or a regulated flow of air in a chamber. Fans may be categorized into:

Axial flow fan

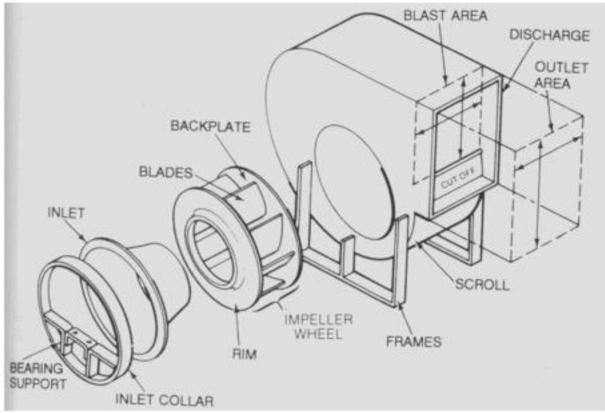
Axial flow fans develop high pressures and is used for moving air through long sections of ductwork.

The fan can be made integral with the ductwork removing the need for a base.

Centrifugal fan

Compared to a propeller fan used in exhausts, the centrifugal fan has characteristics that make it desirable for duct work.

It builds more pressure from the inlet to the outlet and moves more air with more pressure.



(Above). Centrifugal fan exploded view http://4.bp.blogspot.com/--rI7xfZDEE2A/UQIXFdu0vRI/AAAAAAAAADQ/kGYE-H9oJoA/s1600/AS+FAN.png

Centrifugal fan http://b2bimg.bridgat.com/files/Double_Inlet_Centrifugal_Fan.jpg

AIR FILTERS

A particulate air filter is a device composed of fibrous materials which removes solid particulates such as dust, pollen, mould and bacteria from air. A chemical air filter consists of an absorbent (example activated charcoal) or catalyst. Air filters are used where air quality really matters for example ventilation systems and in engines.

Panel type filter

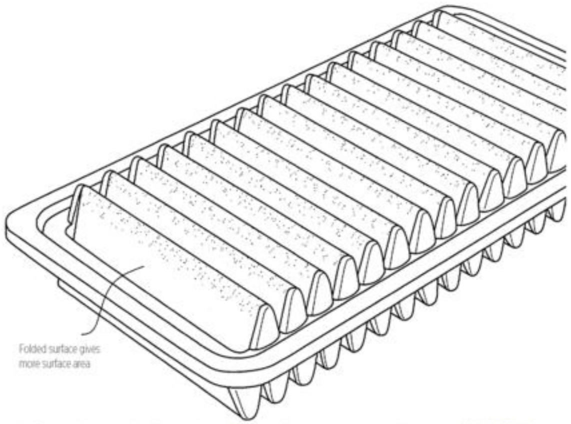
Flat panel or in vee formation to increase the surface contact area.

Available in dry or viscous composition in disposable format for simple fitting within the ductwork.

Dry filters can be vacuum cleaned to extend their life, but needs to be replaced over time.

The viscous filter is coated with an odourless, non toxic, non flammable oil. These can be cleaned in hot soap solution and recoated with oil.

(Above). Panel type air filter http://www.permatron.com/media/22225/permatron-model-in-washable-filter.jpg



(Above). Panel type air filter http://www.freepatentsonline.com/6986799-0-large.jpg

Bag type filter

Provides large contact area.

When the blower is inactive the bag hangs limply.

Resumes horizontal profile during operation.

Fabric bags can be washed and periodically replaced.

(Above). Bag type air filter http://www.airflowukltd.com/image_library/library/a/air/airflowukltd.com/orig_FilterBag.jpg

(Above). Electrostatic filter for HVAC systems
http://hi.atgimg.com/img/x/8888/051111023259_ca.jpg

Filter type	Pros	Cons	Characteristics	Notes
Fiberglass panel Filters	Inexpensive, Low air flow restriction	Not efficient, allows most dust to pass through	Disposable, Filter thickness ranges between 1" to 2"	Since they allow most dust to pass trough they are possibly the worst choice for a ventilation system
Media Air Filter Pads	Low air flow restriction, frequent change not necessary as a pleated filter	Messy removal and maintenance difficulty in removing from frame and fitting	Disposable, ½, 1 and 2 inch thicknesses available	Very high dust loading capacity, frequent changes not necessary, made from polyester fibre bonded together
Electrostatic air filters	Permanent and washable, moderate airflow restriction, generally lasts for few years, high dust loading capacity, no electricity required, lower maintenance and running cost	Cleaning required once in a month	Cleaning easy, washable and can be vaccumed, ½ and 1 inch thickness available	They last years if maintrialained properly, they are green unlike the disposable air filters, some brands use anti microbial protection which inhibits the growth of mould on the fibre material

(Above). Comparative analysis of few variants of filters

Electrostatic filter

It has an ionizing area to which the dust particles cling by acquiring a positive charge.

Cartridge filters

Generally used as airfilter for automobiles, Cartridge filters offer the ease of changing and easy maintenance, they can be equipped with electrostatic fibre for dust retention. They offer very good air flow.

(Above). Cylindrical cartridge filters
http://www.nordic-air--filtration.com/sites/default/files/styles/product_display/public/mediearkiv/products/cylindrical_abs_cartridge_web.jp

Other

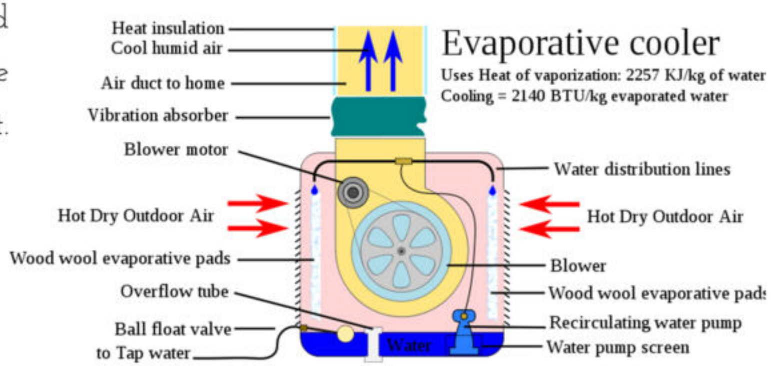
methods for ventilation and cooling

8.1.1 Evaporative cooling technique

An evaporative cooler is a device that cools air through the evaporation of water. Evaporative cooling differs from tyical air conditioning systems which use vapour compression and absorption refrigeration cycles.. The temperature of dry air can be dropped considerably by phase change of liquid water to vapour at a much lower cost than air conditioning. Evaporative cooler works better in drier climates and adds moisture to the dry air. A simple example of evaporative cooling is the body perspiration, or sweat secreted by the body to regulate it's temperature. Evaporative cooling is dependant on the temperature and the humidity of the air. Hot and humid places don't benefit from evaporative cooling and it creates more discomfort. (Evaporative cooler, wikipedia n.d.)

8.1.2 How it works

Evaporative cooling lowers the temperature of the air by the latent heat of evaporation, changing water to water vapour. The energy of the air remains constant in the process. The warm air outside is used to evaporate the water . The relative humicity increases to 70-% to 90% which inturn may reduce the cooling effect of human perspiration.



(Above). Cooling cycle of an evaporative cooler
http://en.wikipedia.org/wiki/File:Evaporative_cooler_annotated.svg

8.1.3 Materials used

Traditionally evaporative cooler pads consist

(Above). Flow diagram of a Ranque-Hilsch Vortex tube
http://en.wikipedia.org/wiki/File:Tube_de_Ranque-Hilsch.png

of grass or wood fibre inside a containment net, but plastics and melamine paper are entering use as a cooler pad media. Wood fibres absorb some of the water and has a larger surface area which allows it to cool the passing air to a much lower temperature than the synthetic materials. But wood fibre is known to host mould and mildew which is absent when synthetic padding is used. (Evaporative cooler 2013)

8.2.1 Vortex cooling

The vortex tube generally called the Ranque-Hilsch vortex tube, is a device which separates compressed air into hot and cold streams.

Pressurized gas is injected tangentially into a swil chamber and accelarated to a high rate of rotation. Due to a conical nozzle at the end of the tube, only the outer shell of the compressed gas is allowed to escape from there. The remainder gas then forms an inner vortex of reduced diameter and escape from the other side of the tube.

They are not as effective as a traditional air-conditioning equipment . They are used for inexpensive spot cooling where compressed air is available.

8.2.2 Area of use

Commercial vortex tubes are designed for industrial applications to produce a temperature drop of about 26 degree Celsius. With no moving parts, no electricity and no Freon, a vortex tube can produce refrigeration upto 6,300 kJ using only filtered compressed air at 100PSI (689 kPa). A control valve in the hot air exhaust adjusts temperatures, flow and refrigeration over a wide range. (Vortex tube, wikipedia n.d.) (Belden n.d.)

Design brief

The revised one

9.1 Insights from the technological studies.

The techlological studies presented us with an over view of the possible ventilation systems and the components available to achieve our task. Firstly talking about the users both primary and secondary. Equal weightage needs to be given for the passengers comfort as well as the simplicity of the product so that its hassle free in maintenance.

9.2 Passenger considerations

Passengers are the ones who are going to spend the maximum time in the compartment and primarily providing them with a fresh clean airy environment is a must. Since all the windows are going to be closed in this scenario, it is necessary that the environment is airy as possible to avoid any feeling of suffocation or claustrophobia. Since air will be blown by ducts / fans with a force it is necessary to place the air vents at such points that it does not blow on their faces or body directly in any way to cause discomfort. The ventilation system also aims at cutting down the ambient noise levels which is prevalent due to open windows. The ventilation equipment should not be too noisy which creates a problem in the passenger coach.

Creating this ventilation system will create distinct passenger cabin separated from the entrance and the toilets similar to airconditioned compartments which will solve the problem of foul air entering into the passenger spaces. There should not be a problem of rainwater dripping into the passenger space.

9.3 Considerations for the maintenance crew

The maintenance cre is the secondary user in this case. Their responsibility involves ensuring that the equipment remains in a good working condition for a journey. Mainly their tasks involves cleaning and changing of filters from time to time so that a proper airflow is maintained in the passenger space. Electrostatic air filters are proposed for the project as they have long service life and are easy to clean by blowing compressed air or vaccum cleaning. Generally these filters need cleaning after several months to upto an year. But assuming the dusty conditions to which they may be exposed, it is preferable to clean them after the end of a trip when the train reaches the yard for the regular cleaning and maintenance for the next trip. The filters should be easily accessible to the crew and easily changed or cleaned.

The revised design brief

The design brief can thus be summarized as, to design a forced air ventilation system for a sleeper class LHB coach with high airflow in the passenger cabin as the windows are closed with an option of cooling the temperature without air conditioning.

“To design a forced air ventilation system for LHB sleeper coaches without provision of openable windows for Indian Railways.”

The system should have high air flow so that openness inside the passenger cabin is maintained, since the windows are closed.

Air vents should be placed at points so that direct air is not blown on the passengers face and body creating discomfort

Rainwater shouldn't drip into the passenger cabin

Equipment shouldn't be too noisy

Air intake preferred from the roof to avoid any chance of foul air from toilet blowing into the system

Placement of equipment where it is not subjected to vandalism and abuse by people

Provision for passengers to control the airflow as per need

The equipment should have a long service life and shouldn't be deteriorated easily by the changing environmental conditions

Available power, generally at 110V D.C needs to be utilized. 415 V, 50 Hz, 3 phase power is available only trains with a generator car like Rajdhani, Shatabdi and Duronto

Maintenance should be easy and hassle free. Electrostatic filters will be provided so that cleaning needs to be done at the end of the trip .

Equipment should be fitted in the existing coaches (LHB) without a change in coach design

The equipment should have a long service life and shouldn't be deteriorated easily by the changing environmental conditions

The wishlist and considerations to be taken for designing the system is shown aside

Ideations

10.1 The initial thoughts

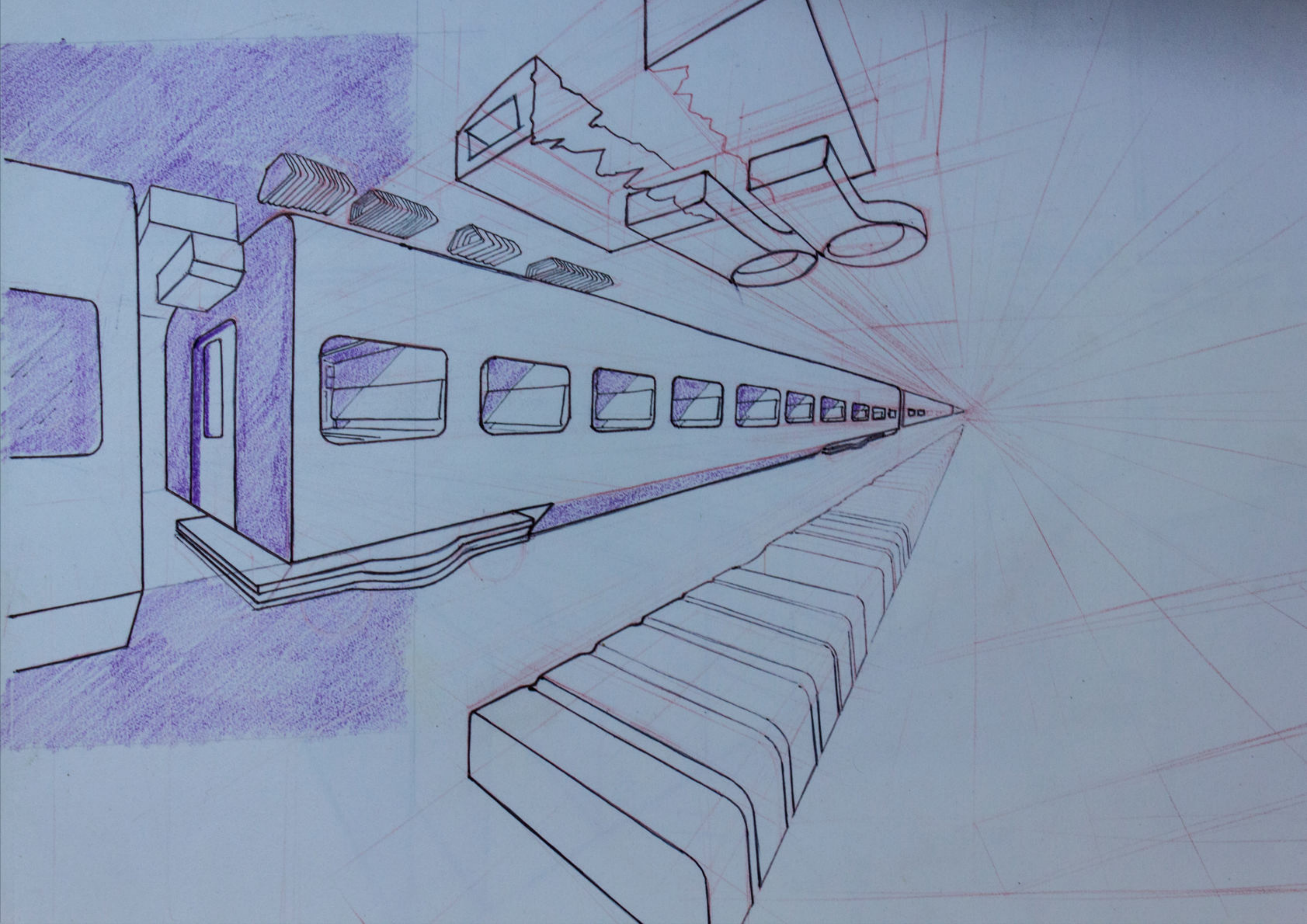
The initial ideas were probably in the direction of a ventilation system with ducts running throughout the length of the passenger space, while the air is fed by means of a roof mounted module housing centrifugal fans which catch air from outside and blow it in the train.

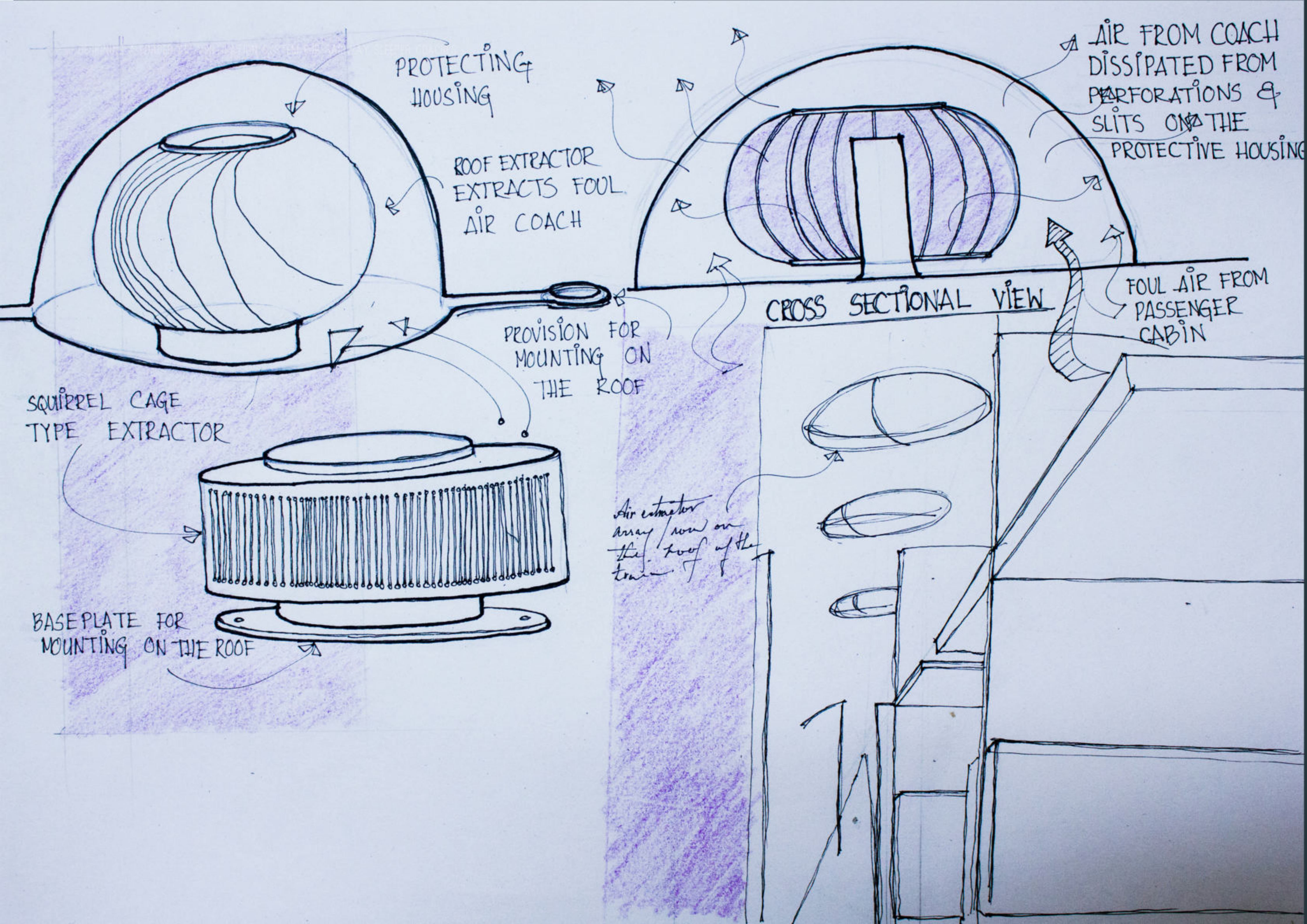
10.2 Reason for intake of air from the roof

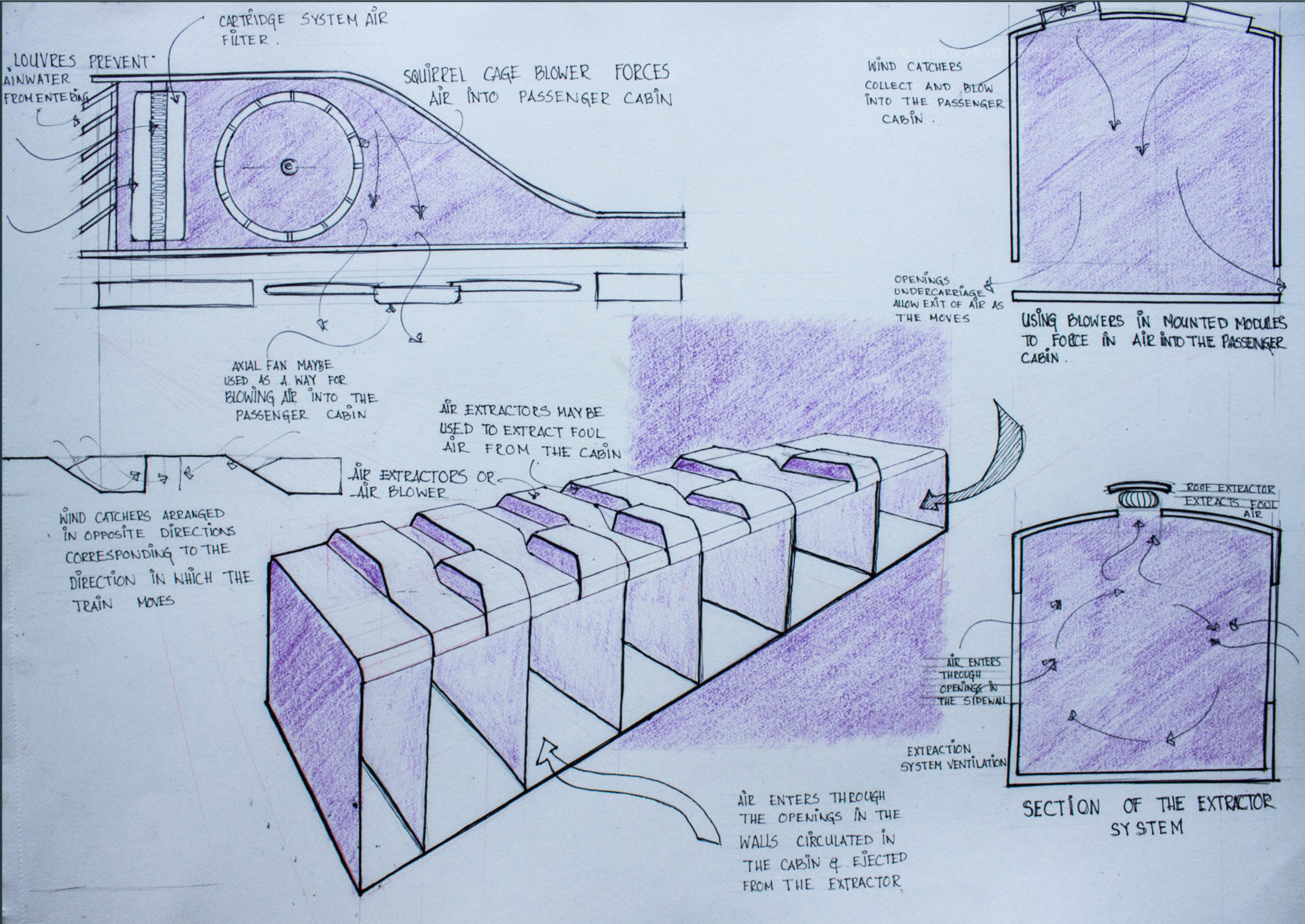
In earlier days when air conditioning was new in trains air used to be sucked from between the coaches and from the sides of the train but the problem of odour from toilet entering the ventilation system was prevalent. However this problem was rectified when the roof mounted airconditioning modules came into use.

The initial idea can thus be said similar to a roof mounted airconditioning module mounted at the ends of the passenger space, in which the airconditioning is replaced by a module comprising of centrifugal fans.

Some other ideas were also thought of based on the extraction system of ventilation in which air extractors are mounted on top of the trains and air is fed through vents at the side of the train body. However it requires a lot of intervention on the side walls and there is complexity involved in the maintenance too. And as discussed earlier extraction system can cause moisture damage in hot and humid climates as moist air tends to condense into the wall cavities.




PROTECTING HOUSING
ROOF EXTRACTOR EXTRACTS FOUL AIR COACH
PROVISION FOR MOUNTING ON THE ROOF
SQUIRREL CAGE TYPE EXTRACTOR
BASEPLATE FOR MOUNTING ON THE ROOF
AIR FROM COACH DISSIPATED FROM PERFORATIONS & SLITS ON THE PROTECTIVE HOUSING
CROSS SECTIONAL VIEW
FOUL AIR FROM PASSENGER CABIN
Air extractor array / row on the roof of the train


CARTRIDGE SYSTEM AIR FILTER.
LOUVRES PREVENT AINWATER FROM ENTERING
SQUIRREL CAGE BLOWER FORCES AIR INTO PASSENGER CABIN
WIND CATCHERS COLLECT AND BLOW INTO THE PASSENGER CABIN.
OPENINGS UNDERCARRIAGE ALLOW EXIT OF AIR AS THE MOVES
USING BLOWERS IN MOUNTED MODULES TO FORCE IN AIR INTO THE PASSENGER CABIN.
AXIAL FAN MAYBE USED AS A WAY FOR BLOWING AIR INTO THE PASSENGER CABIN
AIR EXTRACTORS MAY BE USED TO EXTRACT FOUL AIR FROM THE CABIN
AIR EXTRACTORS OR AIR BLOWER
WIND CATCHERS ARRANGED IN OPPOSITE DIRECTIONS CORRESPONDING TO THE DIRECTION IN WHICH THE TRAIN MOVES
ROOF EXTRACTOR EXTRACTS FOUL AIR
AIR ENTERS THROUGH OPENINGS IN THE SIDEWALL
EXTRACTION SYSTEM VENTILATION
AIR ENTERS THROUGH THE OPENINGS IN THE WALLS CIRCULATED IN THE CABIN & EJECTED FROM THE EXTRACTOR
SECTION OF THE EXTRACTOR SYSTEM

Concept-1

Based on the vortex cooling system. Modules containing vortex tubes are placed lengthwise along the axis of the coach. These individual modules are placed between the outer and inner body shell of the train. The hot air from the vortex escapes from the top of the train while the cold end opens into the passenger cabin and the flow can be regulated by means of louvres. pipes carrying compressed air run along the length of the coach and feed air into each module. The compressed air is stored in tanks at the undercarriage of the train similar to tanks for air brakes.

Working mock up of a vortex tube

A vortex tube was made by following instructions from a do it yourself video in www.ottobelden.blogspot.in using ordinary plumbing fixtures to determine the working and the overall length of such a tube.
Reducer fittings and couplings were used along with pipes of 1 inch diameter.

Pros

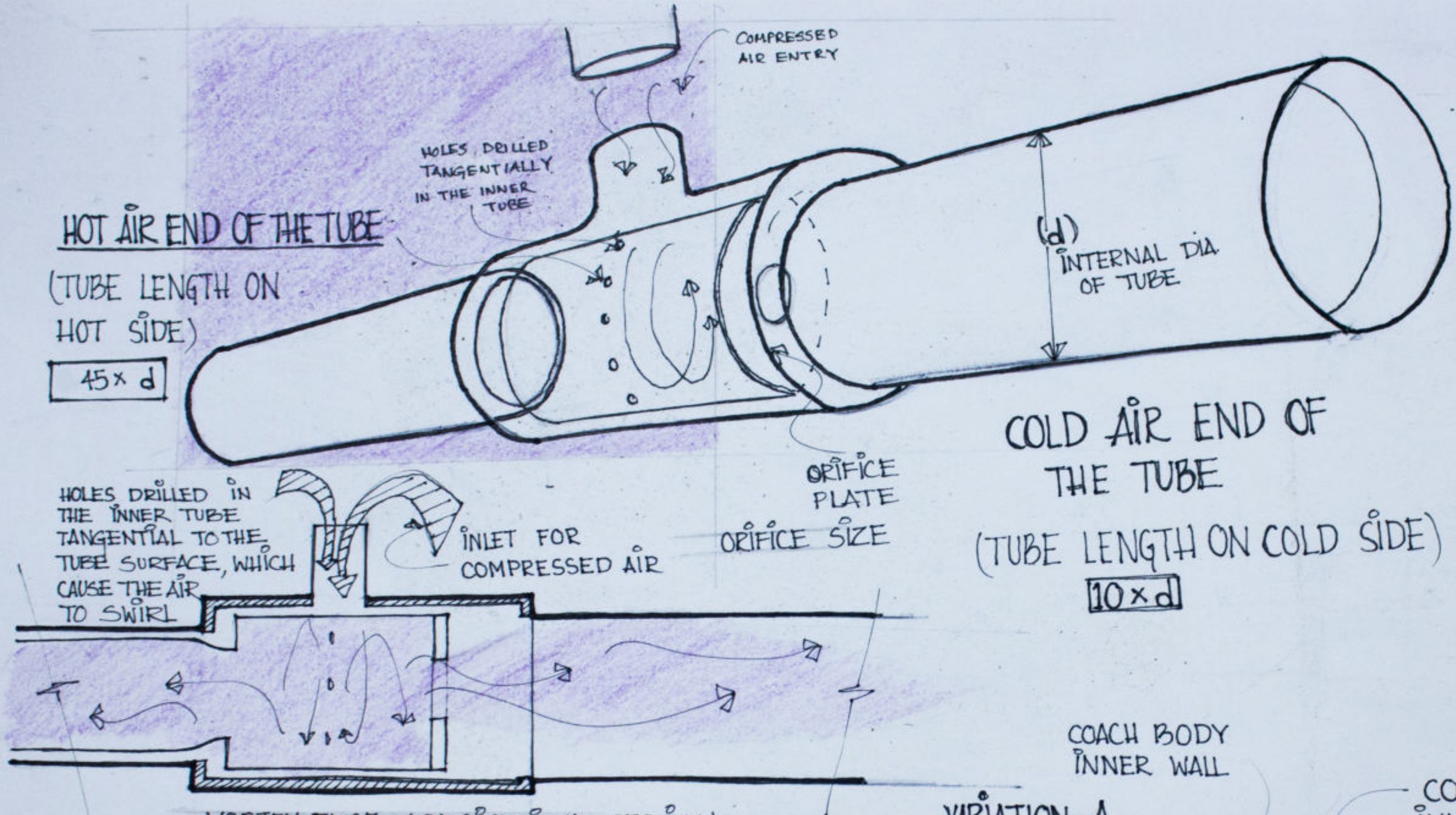
Vortex cooling is low on energy consumption as it does not require electricity to run. Electricity is only needed for air compression in the compressor.
Filters for the air can be installed at a single location near the compressor which makes changing easier.
Since there are no moving parts as such, it's low on maintenance and high on longevity.
The module is concealed and not exposed to the outdoor weather conditions.

Cons

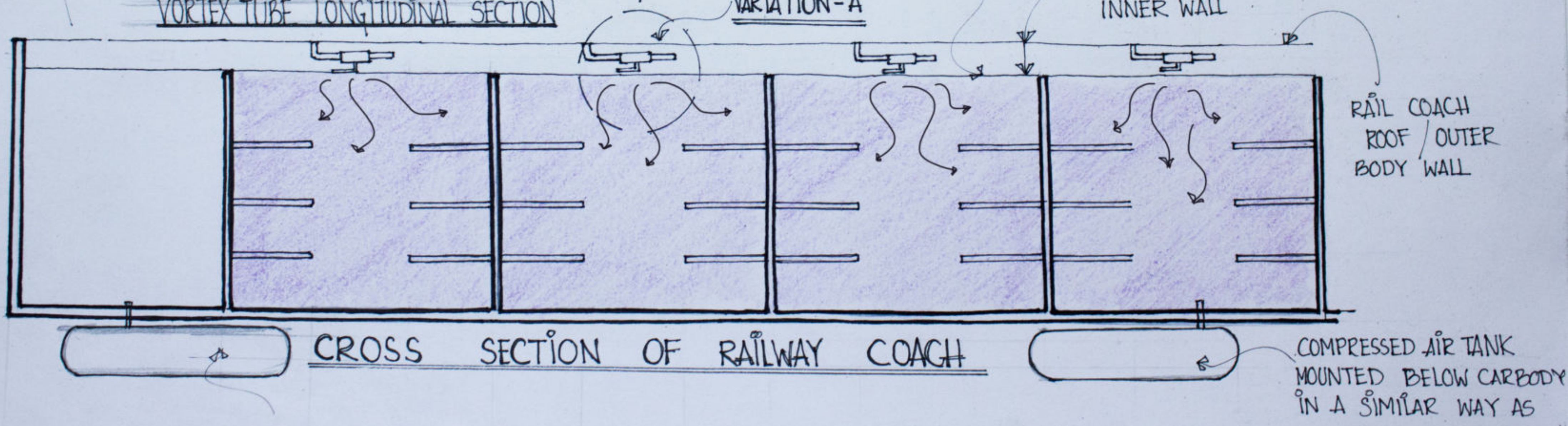
Since the air leaves at a high velocity from an orifice, it can be quite noisy due to the nozzling action of air at high pressure.
Storing a lot of compressed in cylinders can be hazardous, there might be dangers of explosion.

Concept - 1

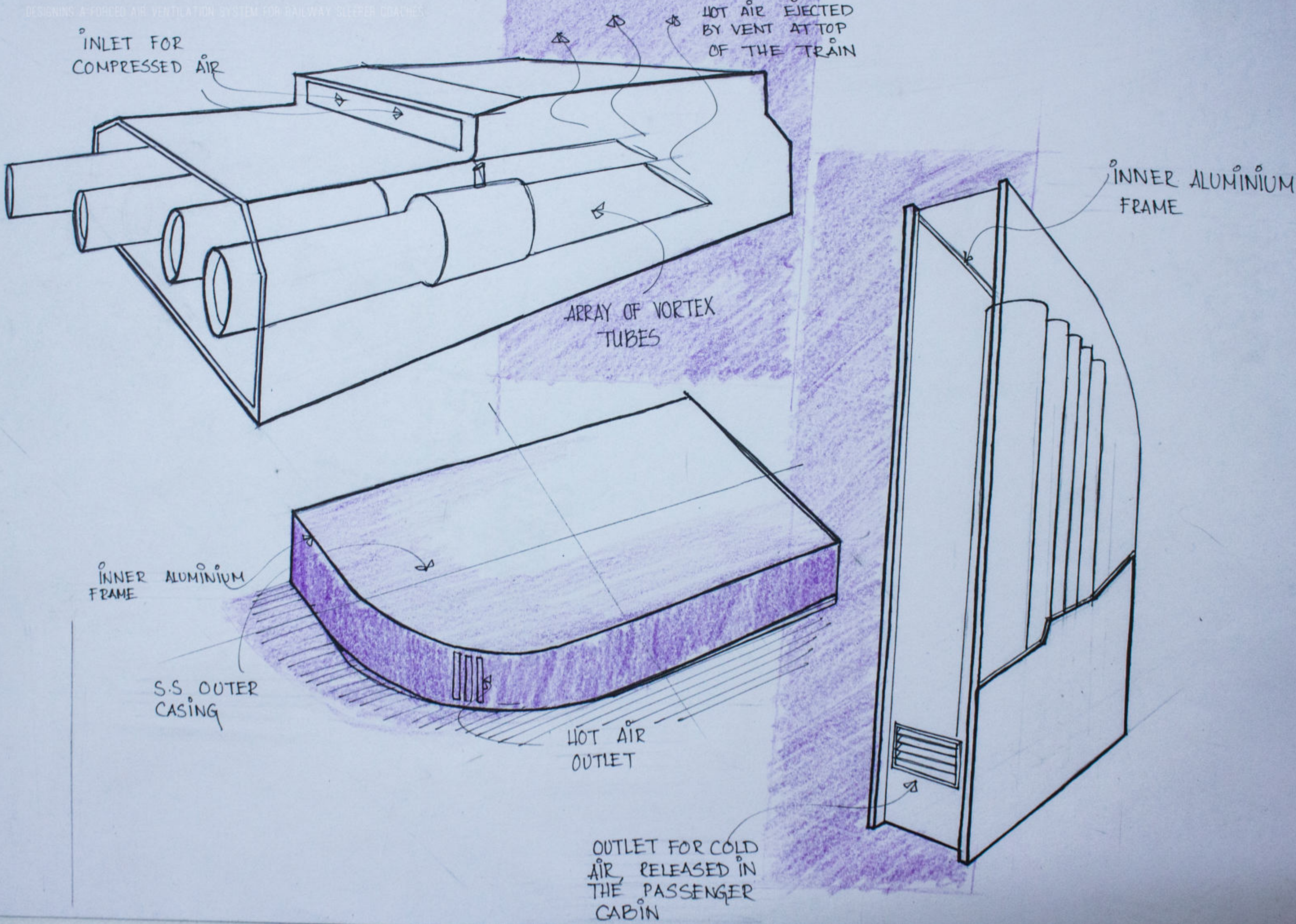
IDEATING ON THE POSSIBILITIES OF USING A RANKE - HILSCH VORTEX TUBE FOR PROVIDING COOL AIR IN THE PASSENGER CABIN.

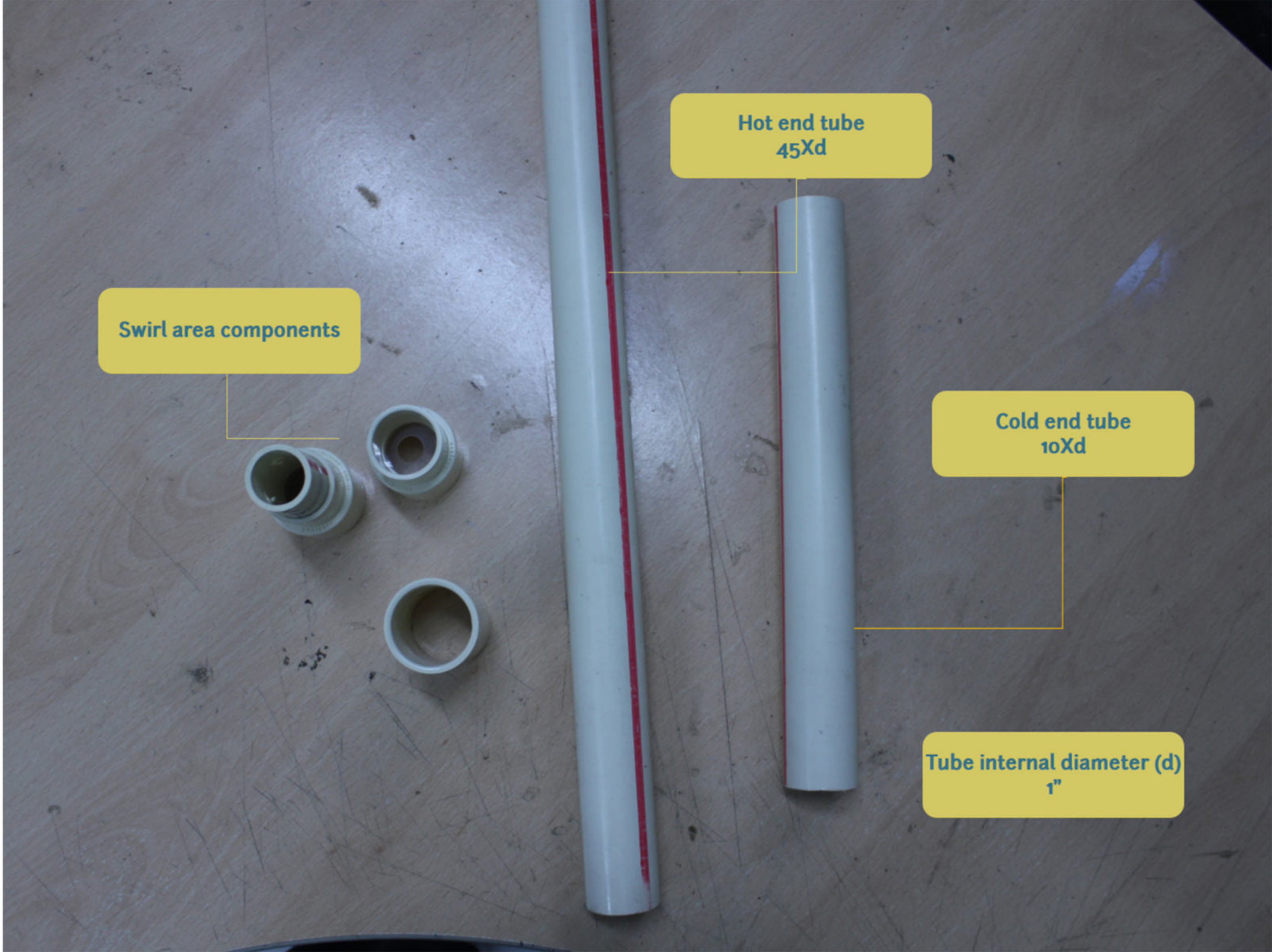


VORTEX TUBE LONGITUDINAL SECTION



CROSS SECTION OF RAILWAY COACH


INLET FOR COMPRESSED AIR
HOT AIR EJECTED BY VENT AT TOP OF THE TRAIN
ARRAY OF VORTEX TUBES
INNER ALUMINIUM FRAME
INNER ALUMINIUM FRAME
S.S OUTER CASING
HOT AIR OUTLET
OUTLET FOR COLD AIR, RELEASED IN THE PASSENGER CABIN


Hot end tube
45Xd
Swirl area components
Cold end tube
10Xd
Tube internal diameter (d)
1”


Holes drilled tangentially


Orifice size ½ d or 0.4 “


Inlet for compressed air

Advantages and disadvantages

A quick recap to the concept of vortex cooling for the passenger compartment. The major points have been highlighted aside.

Advantages

No moving parts means no wear and tear and no maintenance.

Does not require a power source, only compressed air at 100 PSI

Compressed air tanks similar to air brake tanks can be mounted on the underframe of the coach

Air filter needed only at the compressed air source. Which can be distributed via pipes to the vortex modules

Individual vortex modules at every passenger cubicle ensures maximum airflow.

Cooling can be achieved irrespective of the outside atmospheric conditions

Does not use any refrigerant not even water

Not exposed to environmental factors such as rain, dust etc which can reduce its life. Pipes for the same can run along the body shell of the coach

Ambient temperature can be controlled by varying the hot end of the module. Even the hot air can be bypassed in to stabilize temperature extremes

Disadvantages

Storing and carrying a large amount of compressed air is dangerous, it can increase chances of explosion.

Since the air leaves at a high speed from the pipes, distribution of air is not even. It is more like a jet of air, which cannot be distributed over a large area evenly.

The air leaving from the pipes create a gushing sound and thus the equipment is very noisy

Vortex cooling is advantageous for spot cooling

Concept-2

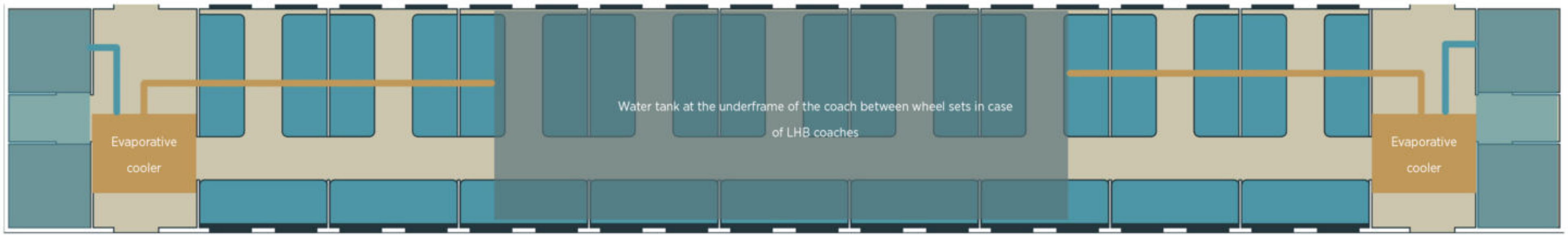
Based on the principle evaporative cooling system, this module sits on top of the roof of the train, just outside the passenger cabin. Water can be used from the water tanks of the train which gets refilled at every station. The waste water from the evaporator may be used for flushing toilets.

The evaporative cooling unit will be mounted on the train with the water retention pads facong the atmosphere. Pipes carrying water from the storage tanks at the underframe of the coach sprays water on the pad. Water over time evaporates from it cooling down the temperature of the incoming air. The excess water drips down the pad due to the sloping profile. The air is further filtered by a panel filter placed midway to the water pad and the blower. A squirrel cage blower is used to blow the air into the passenger cabin..

Pros

Less expensive to install

Estimated cost of installation almost half of airconditioning. (Krigger 2004)



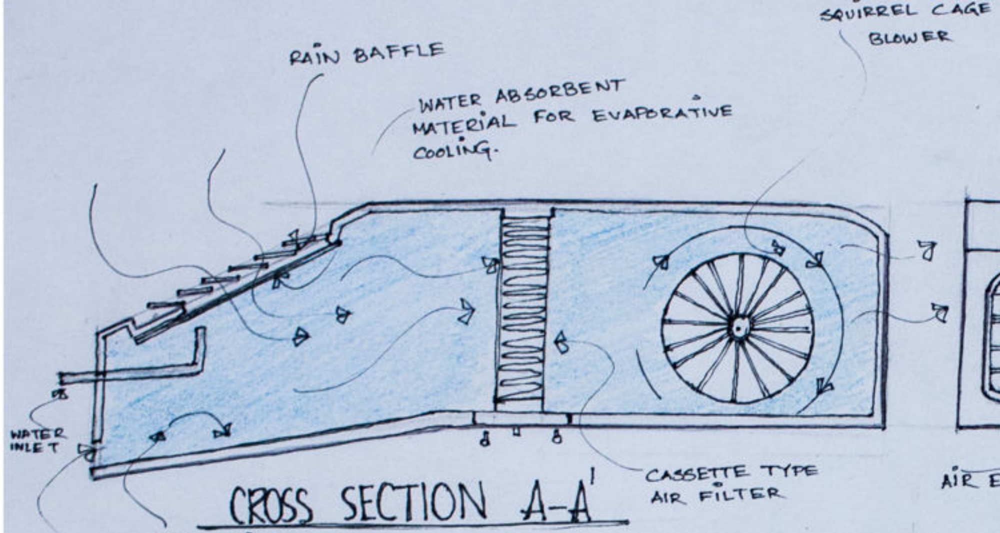
Residual water goes into tank above toilet area and used fur flushing toilets

Schematic layout for water flow in evaporative cooling system proposed for LHB coaches

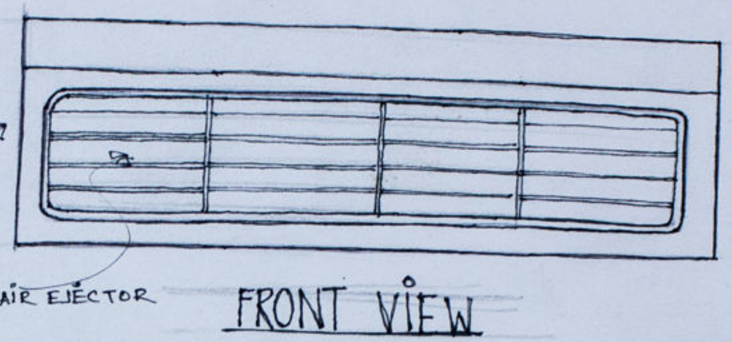
Concept : II

idea of using evaporative cooling for the railway coach . . .

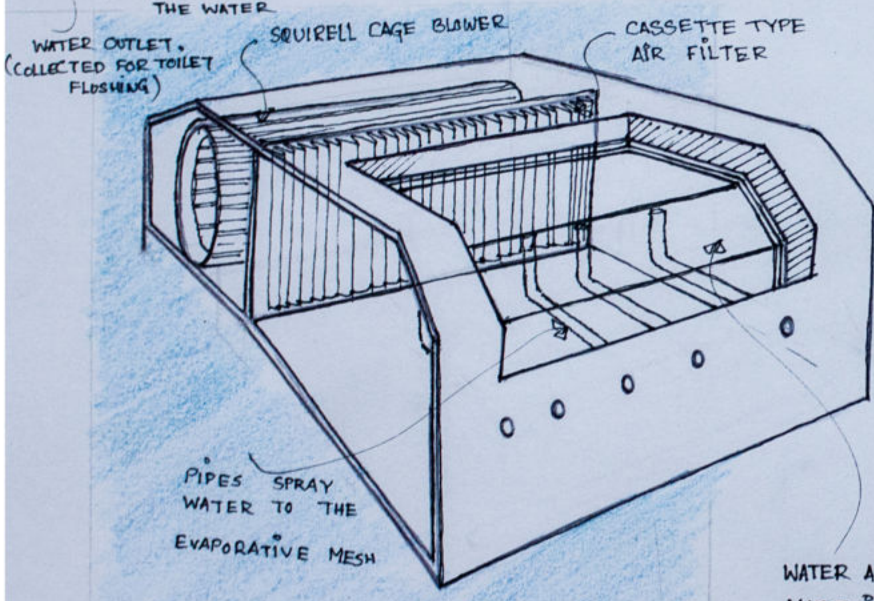
- Pros
- can be used when the train passes through a climatic region having low relative humidity
- Easy installation and maintenance / Ease of change of air filters / accessibility from the coach interior.
- Air collected from the top of the train which eliminates the entry of smell from the toilet.



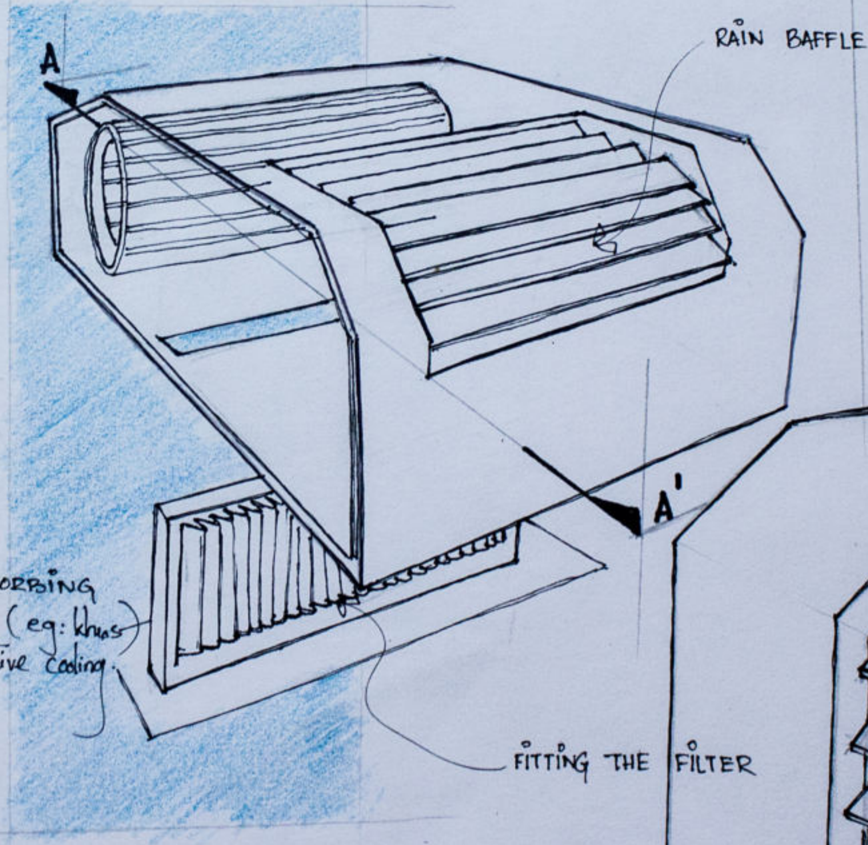
CROSS SECTION A-A'

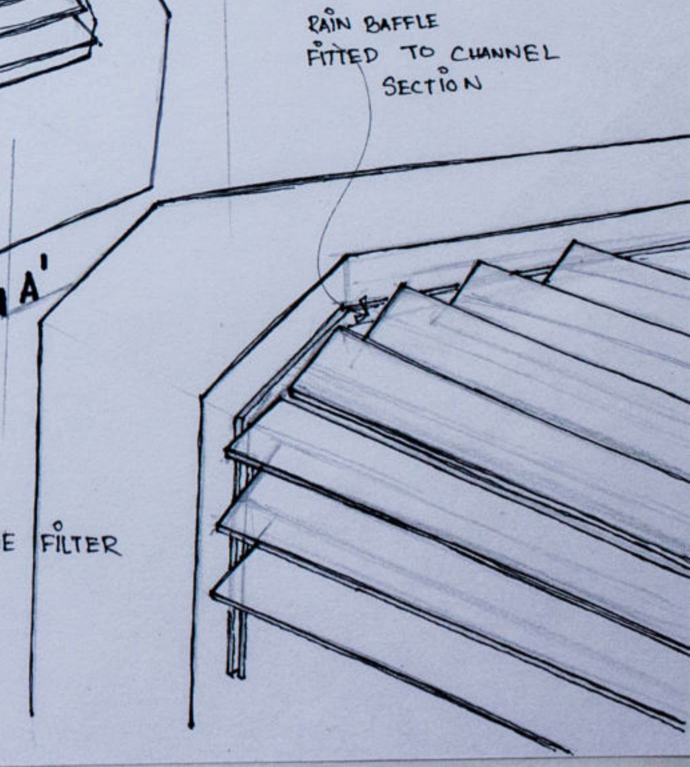


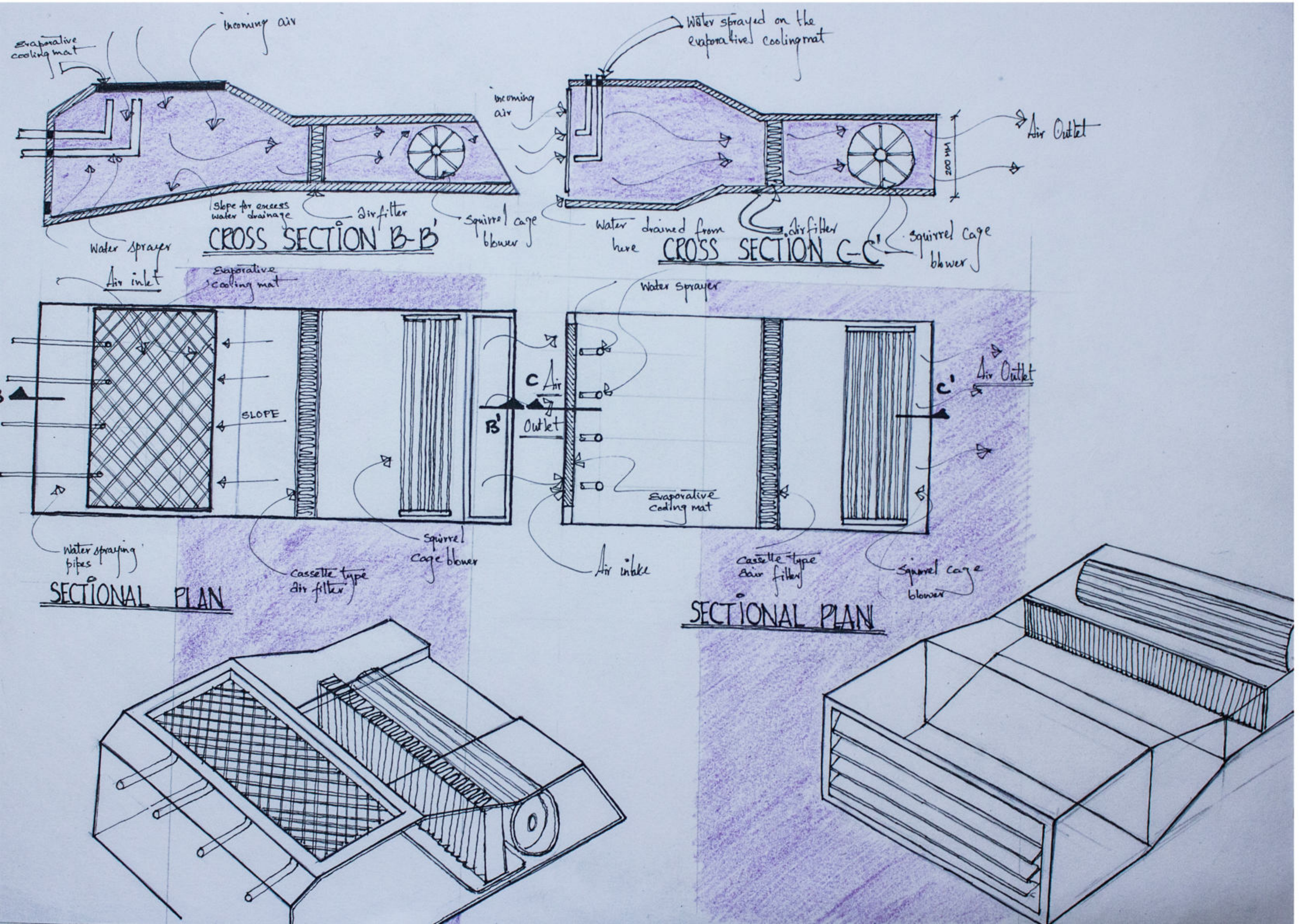
FRONT VIEW



VIEW WITH RAIN BAFFLE REMOVED







incoming air
Evaporative cooling mat
Slope for excess water drainage
airfilter
Squirrel cage blower
Water sprayer
CROSS SECTION B-B'
Water sprayed on the evaporative cooling mat
incoming air
Air Outlet
200 mm
Water drained from here
airfilter
Squirrel cage blower
CROSS SECTION C-C'
Air inlet
Evaporative cooling mat
SLOPE
C
Air Outlet
B'
Water spraying pipes
Cassette type air filter
Squirrel Cage blower
SECTIONAL PLAN
Water sprayer
Air Outlet
C'
Evaporative Cooling mat
Air intake
Cassette type air filter
Squirrel cage blower
SECTIONAL PLAN

Less power consumption

Estimated cost of operation is 1/8th that of refrigerated air (Evaporative cooler 2013)

The pad itself acts as an effective filter. It is capable of removing a variety of contaminants in the air.
Power consumption limited to fan and water pump.
Water is used as the cooling agent which is easily available and less expensive and environment friendly.

Ease of maintenance

The only two mechanical parts fan and water pump are low on maintenance and inexpensive to replace.

Ventilation air

The constant and high volumetric rate of flow rate of air through the chamber reduces the "age of air" in the chamber.
It is very well suited for dry climates.

Cons

Performance

High humidity reduces the effectiveness of the evaporative cooler. Not suitable for places with high relative humidity. In humid conditions dryness may improve thermal comfort.

Comfort

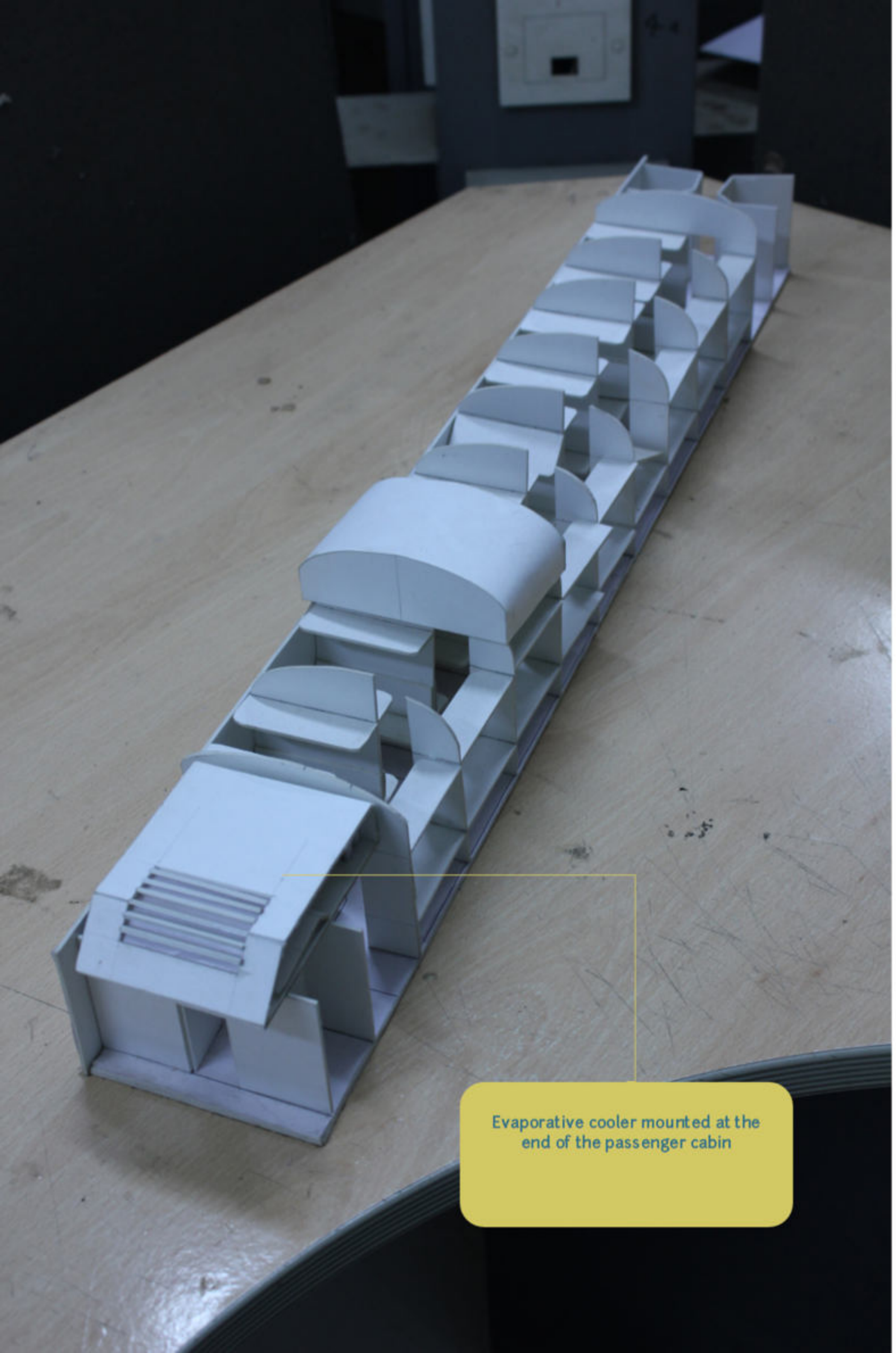
High humidity of evaporative cooler 80% to 90% reduces the evaporation rate of moisture from skin, nose, lungs and eyes.
High humidity even increases chances of corrosion. This can affect a lot of components.

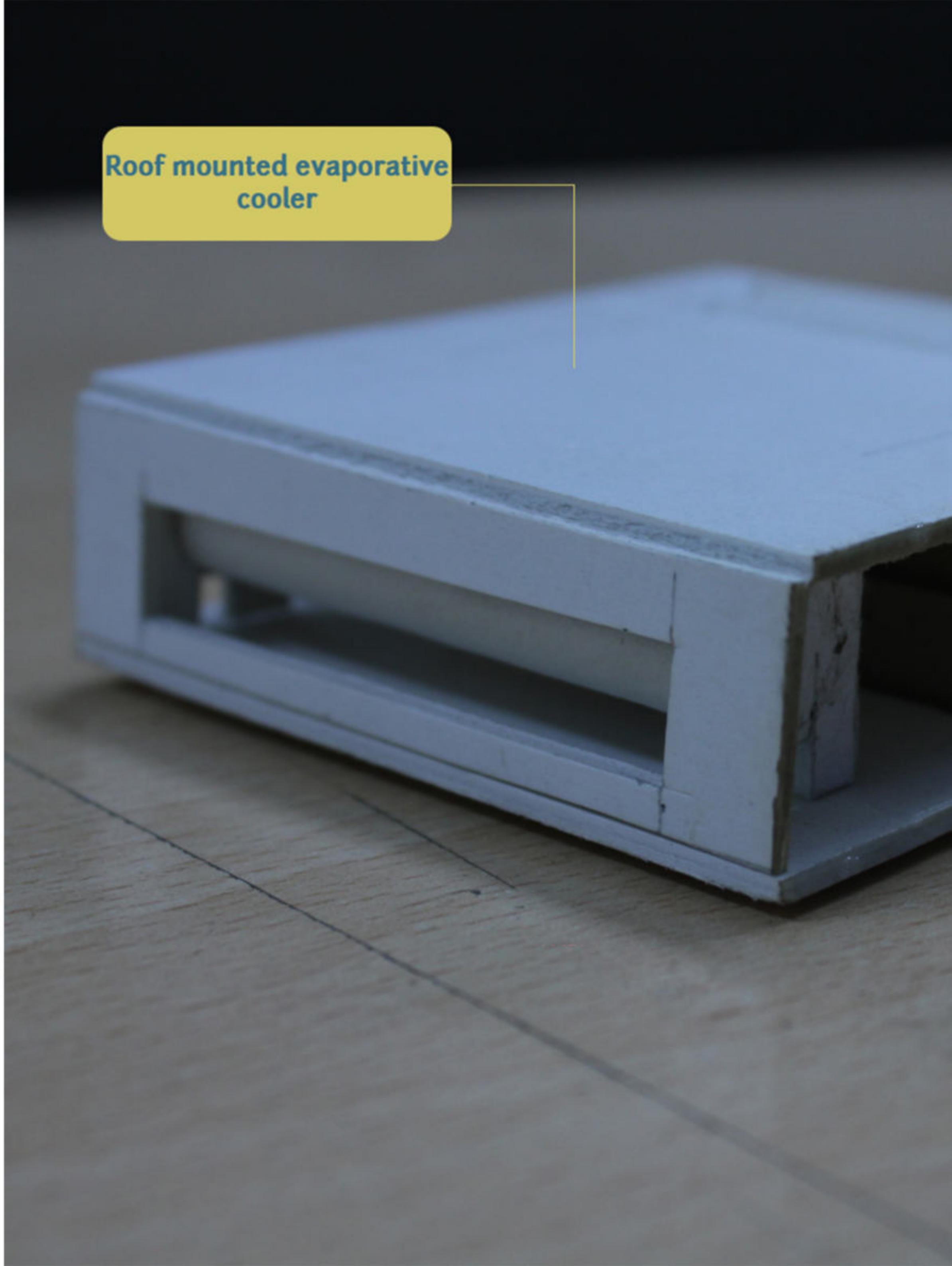
Breeding grounds for mosquitoes.

Evaporative coolers are infamous as they often become breeding grounds for mosquitoes if left unused and unclean. Regular cleaning is necessary for that.

More options

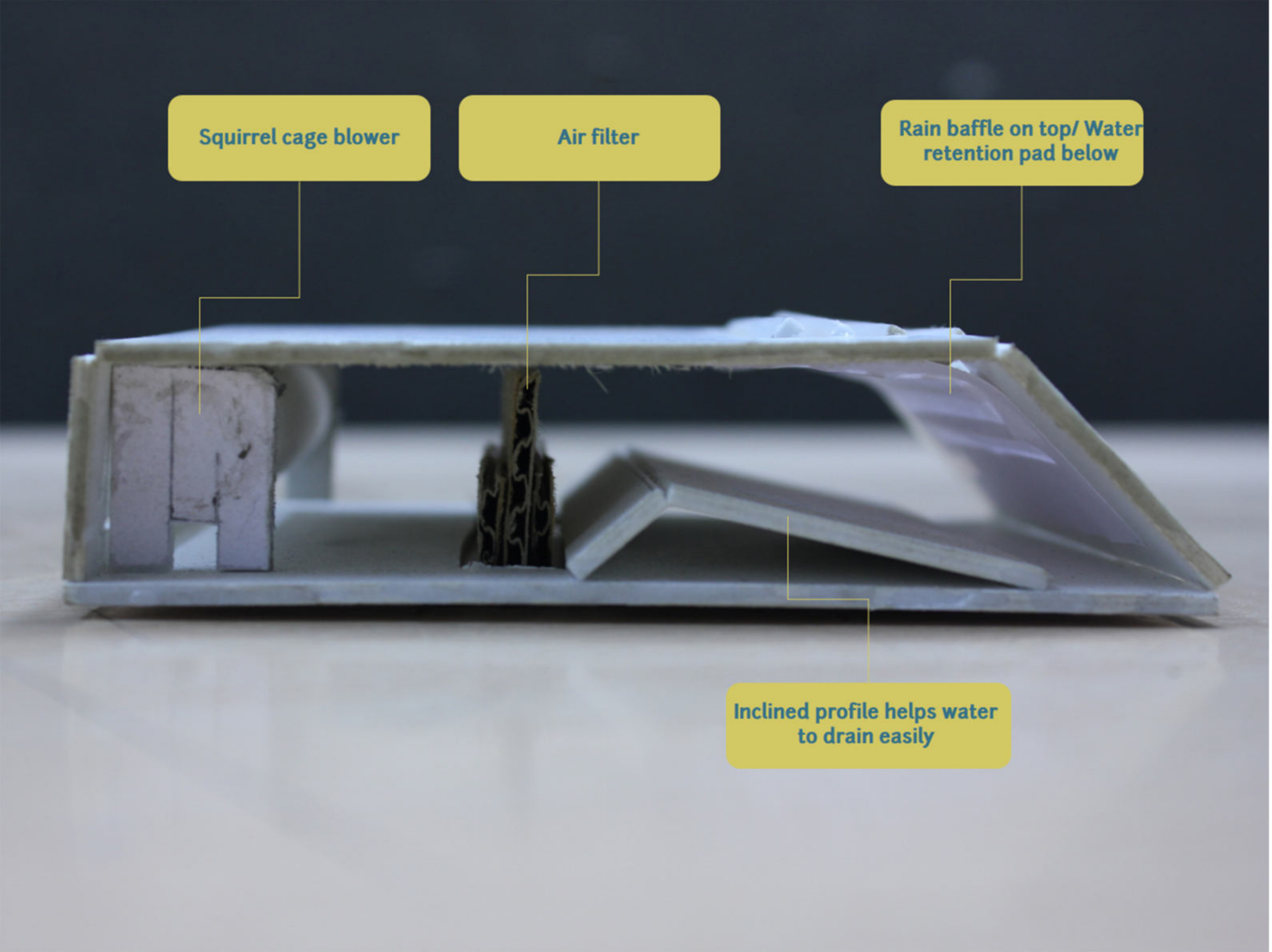
More options are done regarding this concept by adding separate wind catcher units on top of the train at regular intervals in the passenger cabins, which will be discussed later.

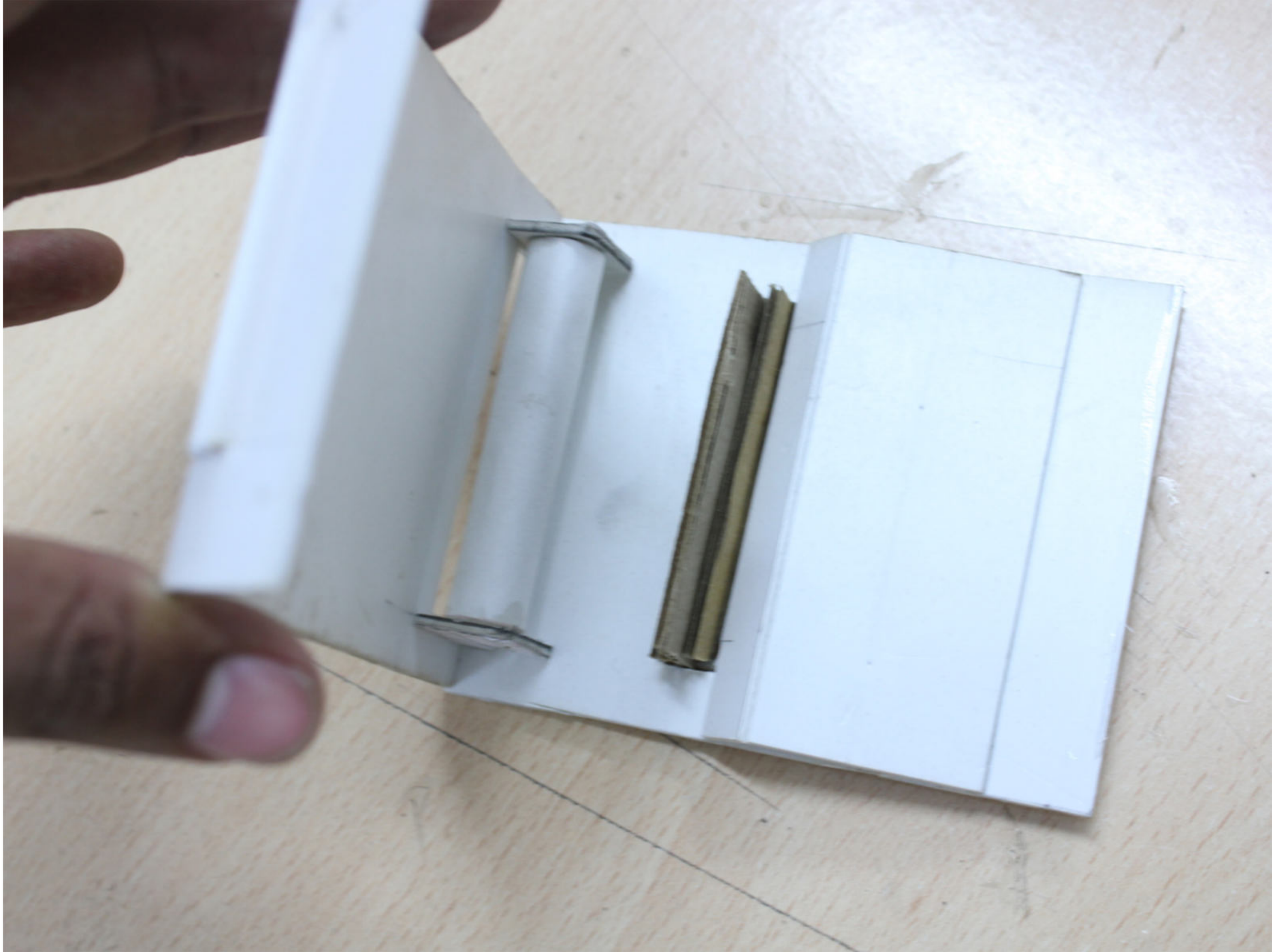

Evaporative cooler mounted at the end of the passenger cabin

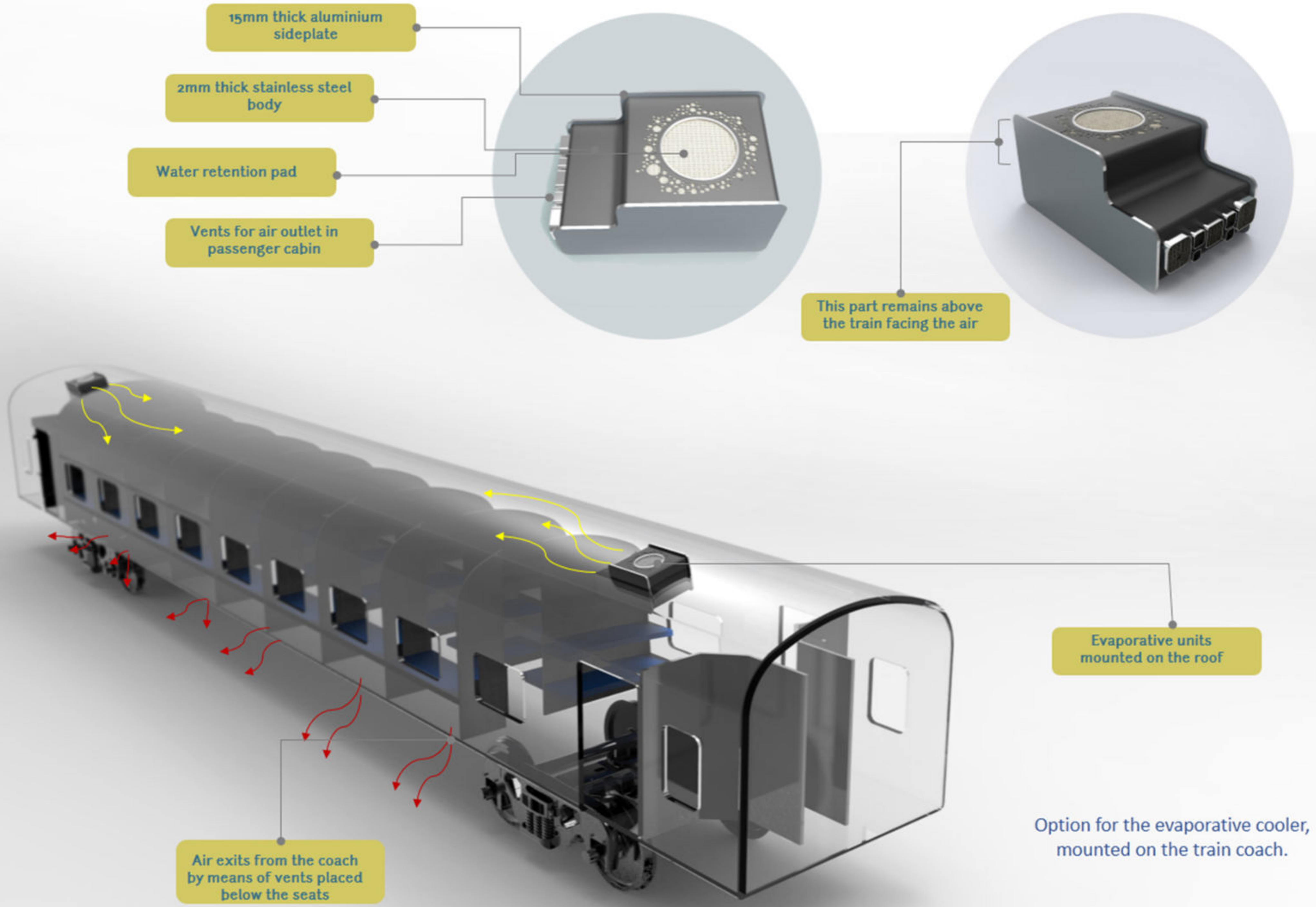

Roof mounted evaporative cooler

Since these modules are mounted at the end of the passenger compartment, a squirrel cage blower is preferred for discharging air as it has more pressure ratio than an axial fan.

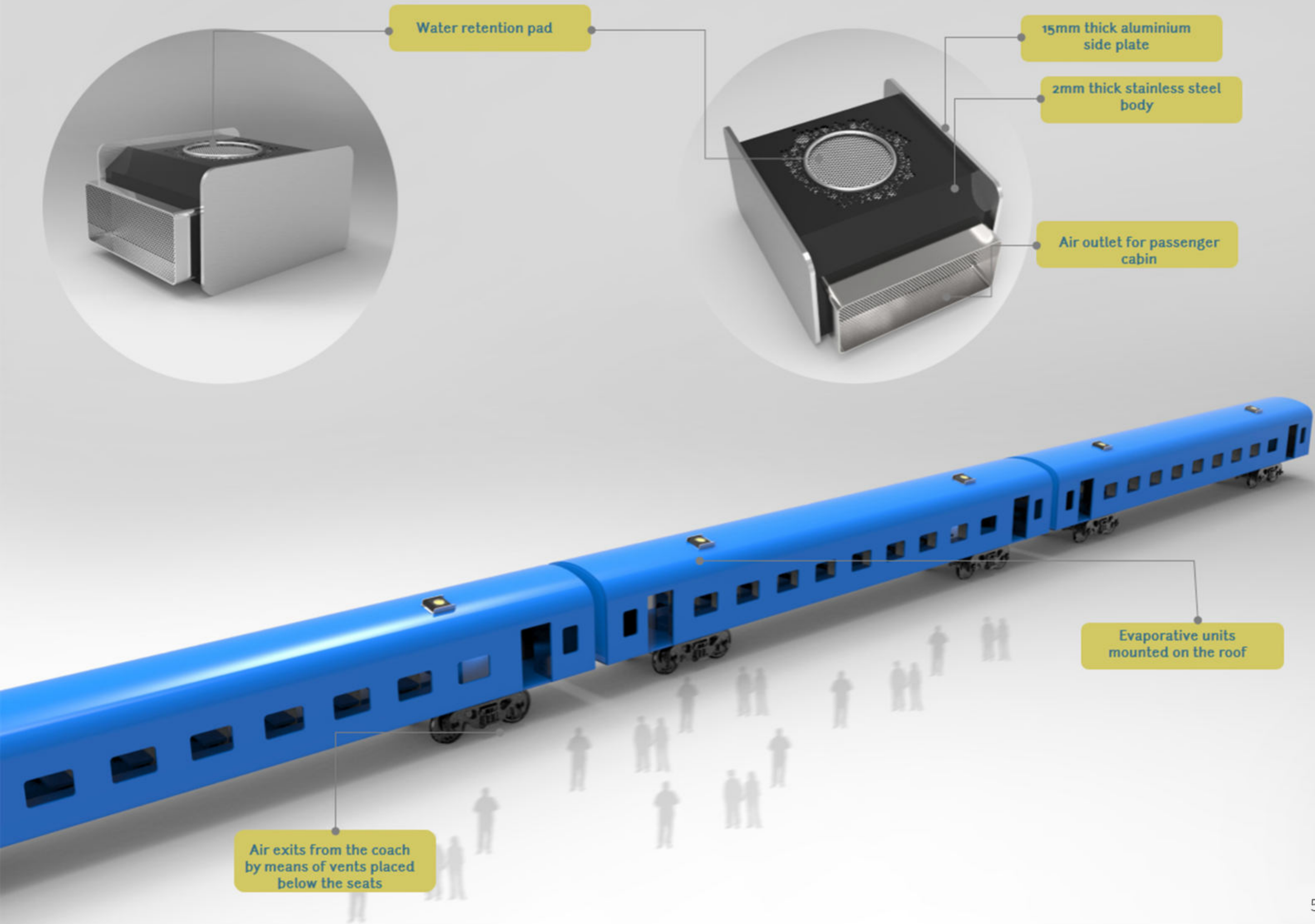
(Right). A squirel cage blower
Image courtesy. . http://www.acsource.com/ProductImages/cagecwLg.jpg

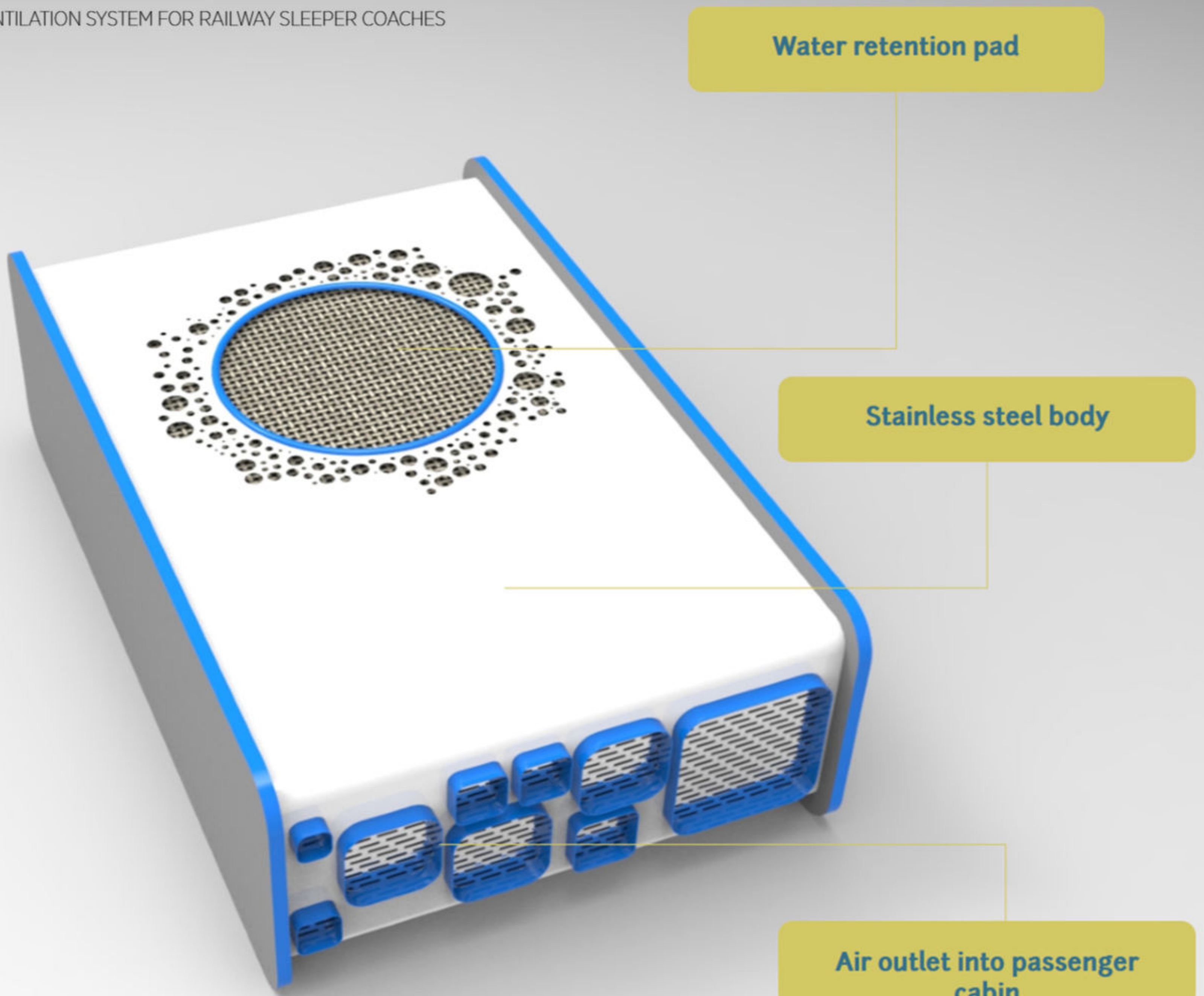

Squirrel cage blower
Air filter
Rain baffle on top/ Water retention pad below
Inclined profile helps water to drain easily

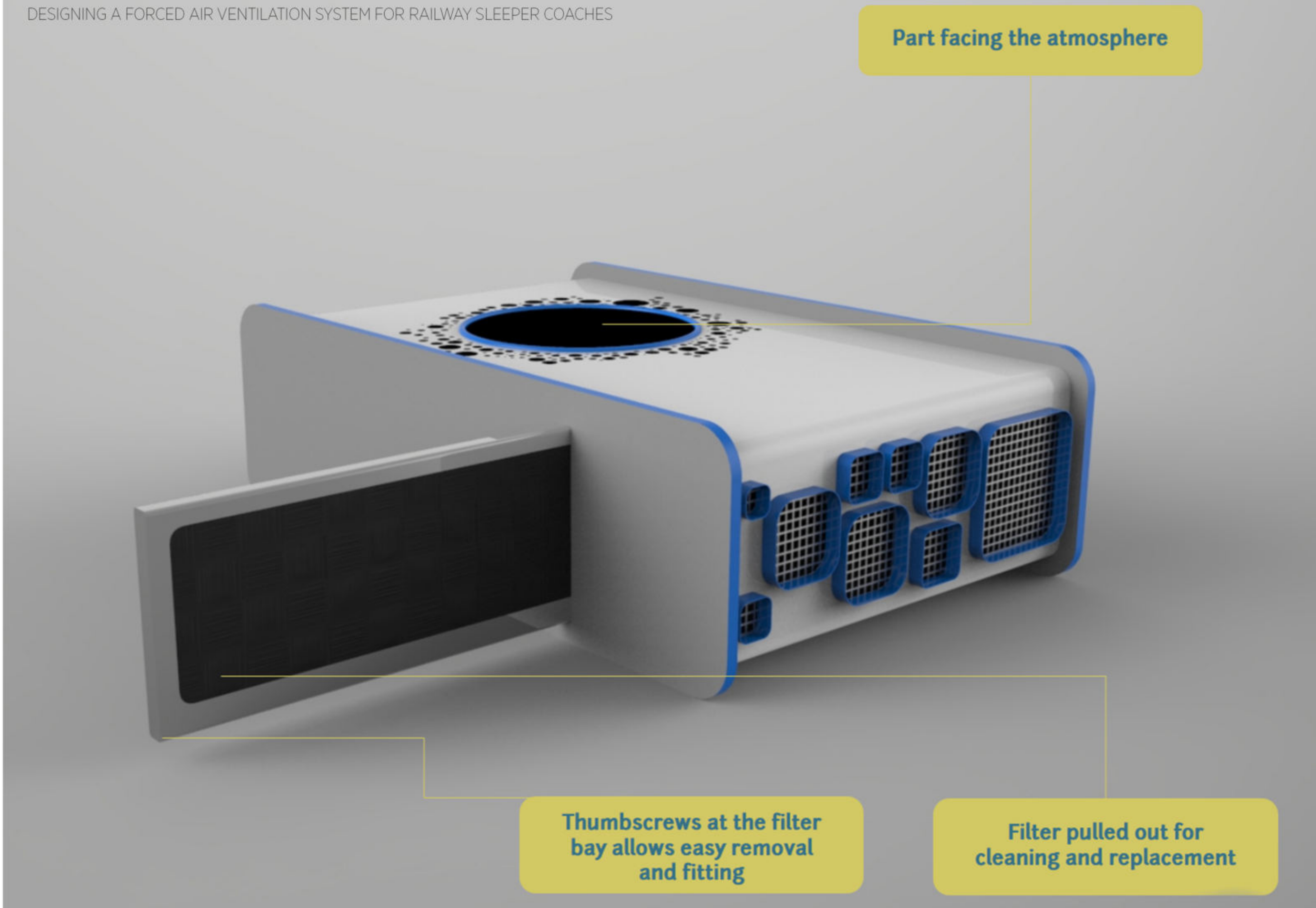


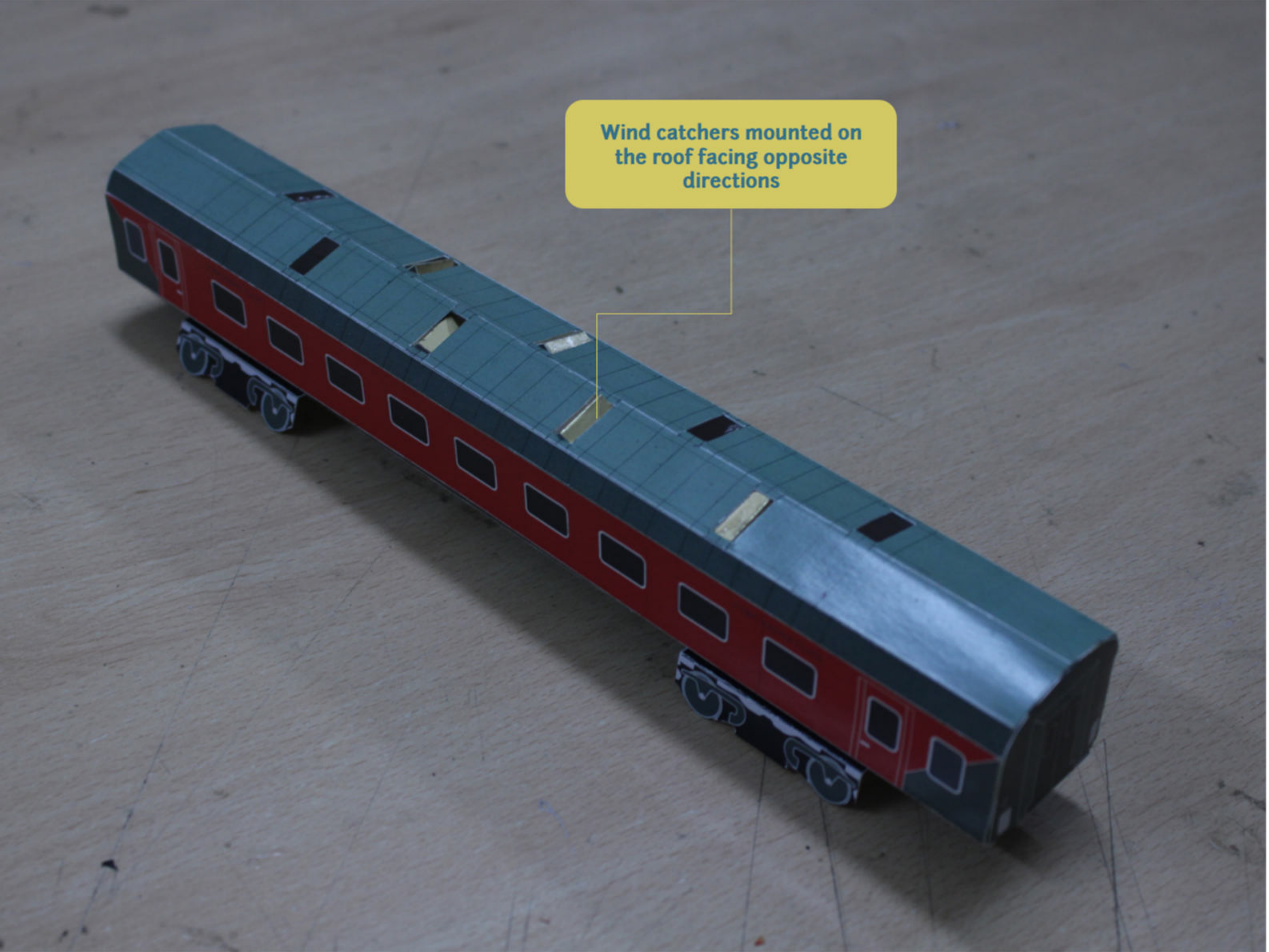


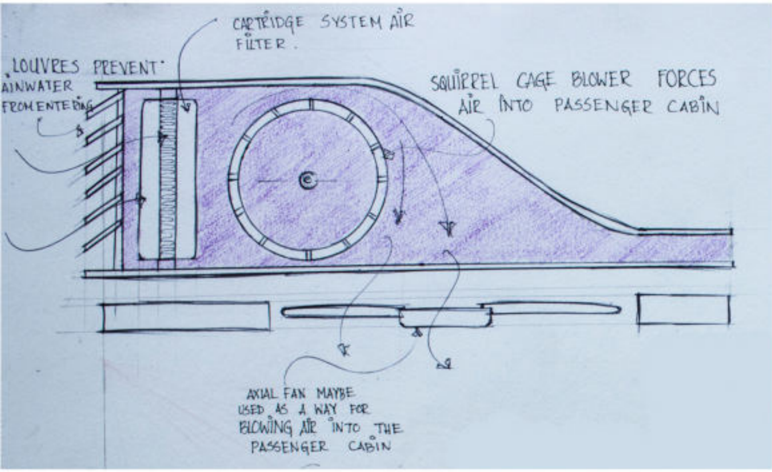
Option for the evaporative cooler, mounted on the train coach.

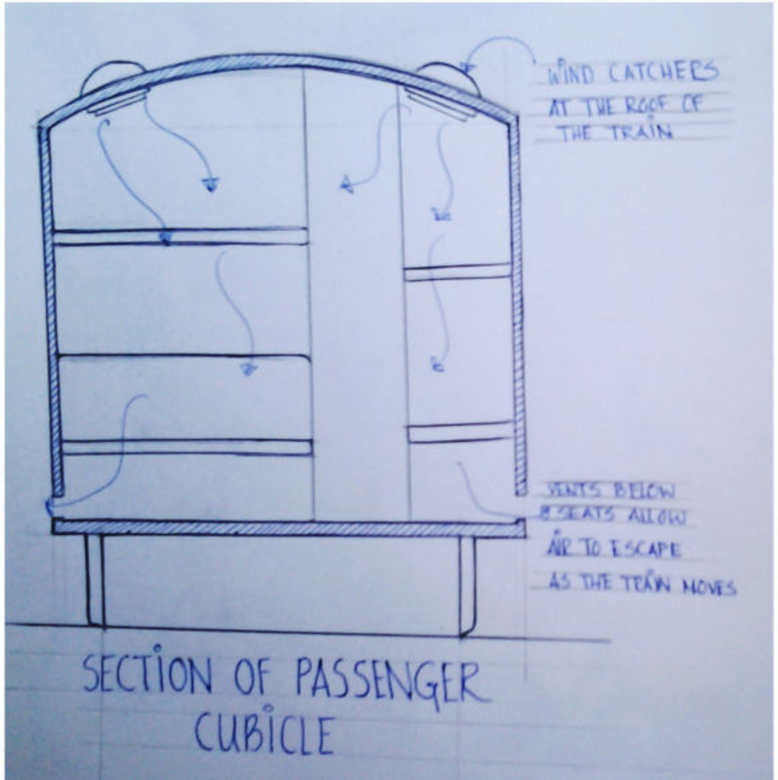

Water retention pad
15mm thick aluminium side plate
2mm thick stainless steel body
Air outlet for passenger cabin
Evaporative units mounted on the roof
Air exits from the coach by means of vents placed below the seats


Water retention pad
Stainless steel body
Air outlet into passenger cabin


Part facing the atmosphere
Thumbscrews at the filter bay allows easy removal and fitting
Filter pulled out for cleaning and replacement


Wind catchers mounted on the roof facing opposite directions





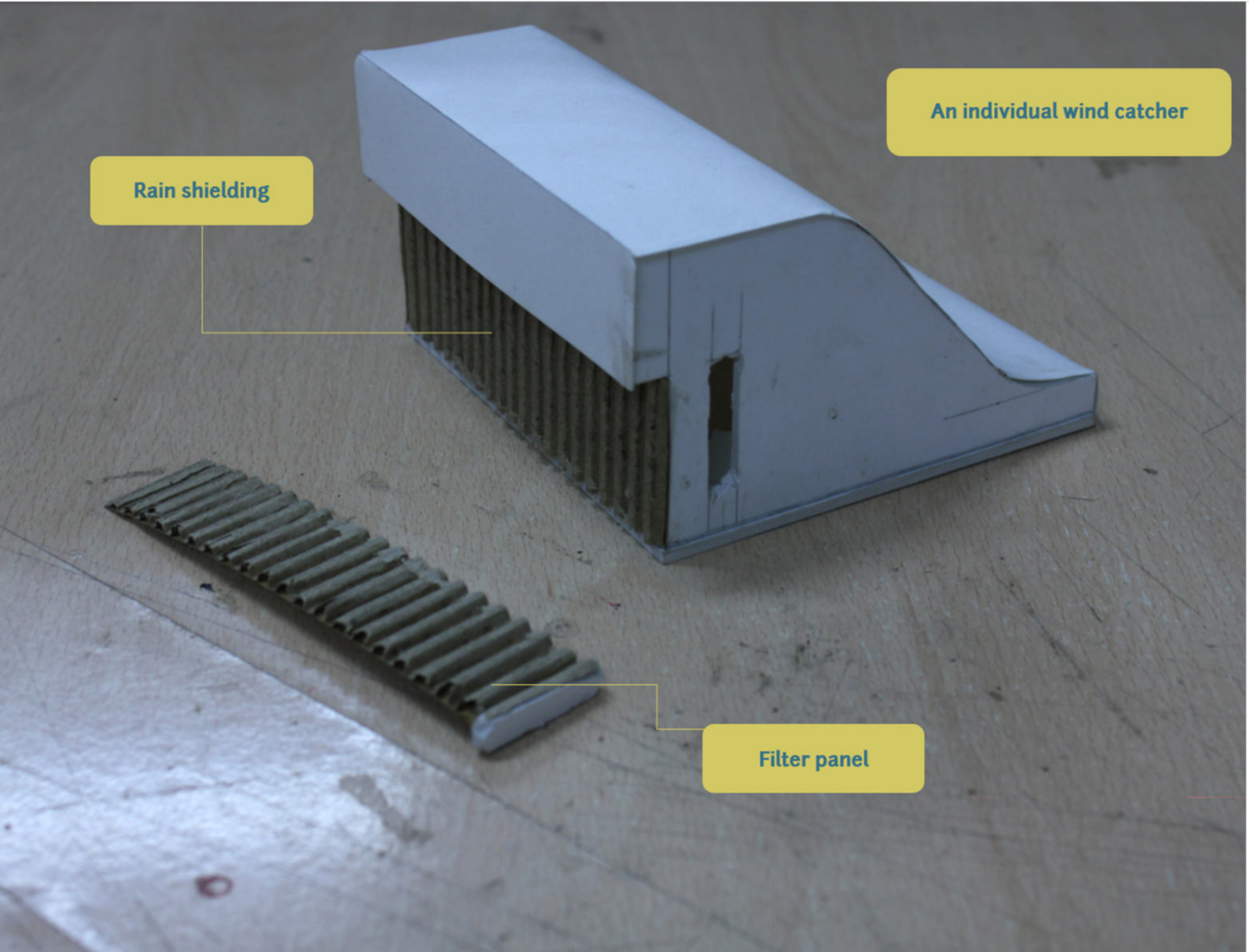
Option-1

This concept can be further extended by adding wind catching units on top of the train roof above each passenger partition. The wind catching units are fitted with cartridge type air filters or panel electrostatic filters which can be quickly cleaned by blowing compressed air on them or by vacuum cleaning. One of the idea based on this option is to place the wind catchers facing opposite directions which corresponds to the direction in which the train moves. The modules which face the opposite direction can be cleaned at that time and vice versa.

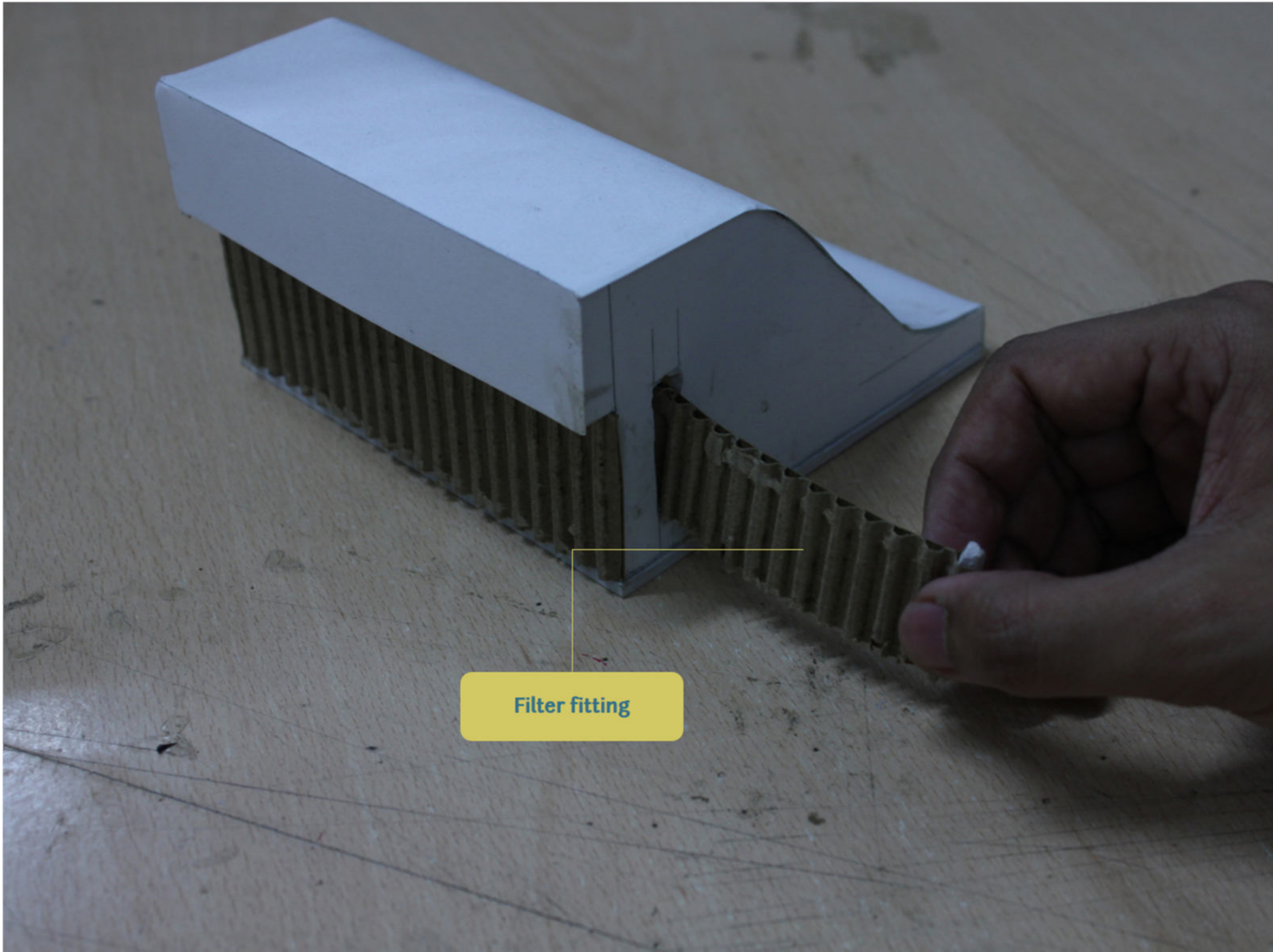
The wind catchers are provided with baffles to avoid entry of rainwater in the passenger cabin along with other provisions for avoiding the same. The wind catchers along with the cooler unit maximizes the airflow in the passenger space making it more airy and comfortable

Passenger control of air flow

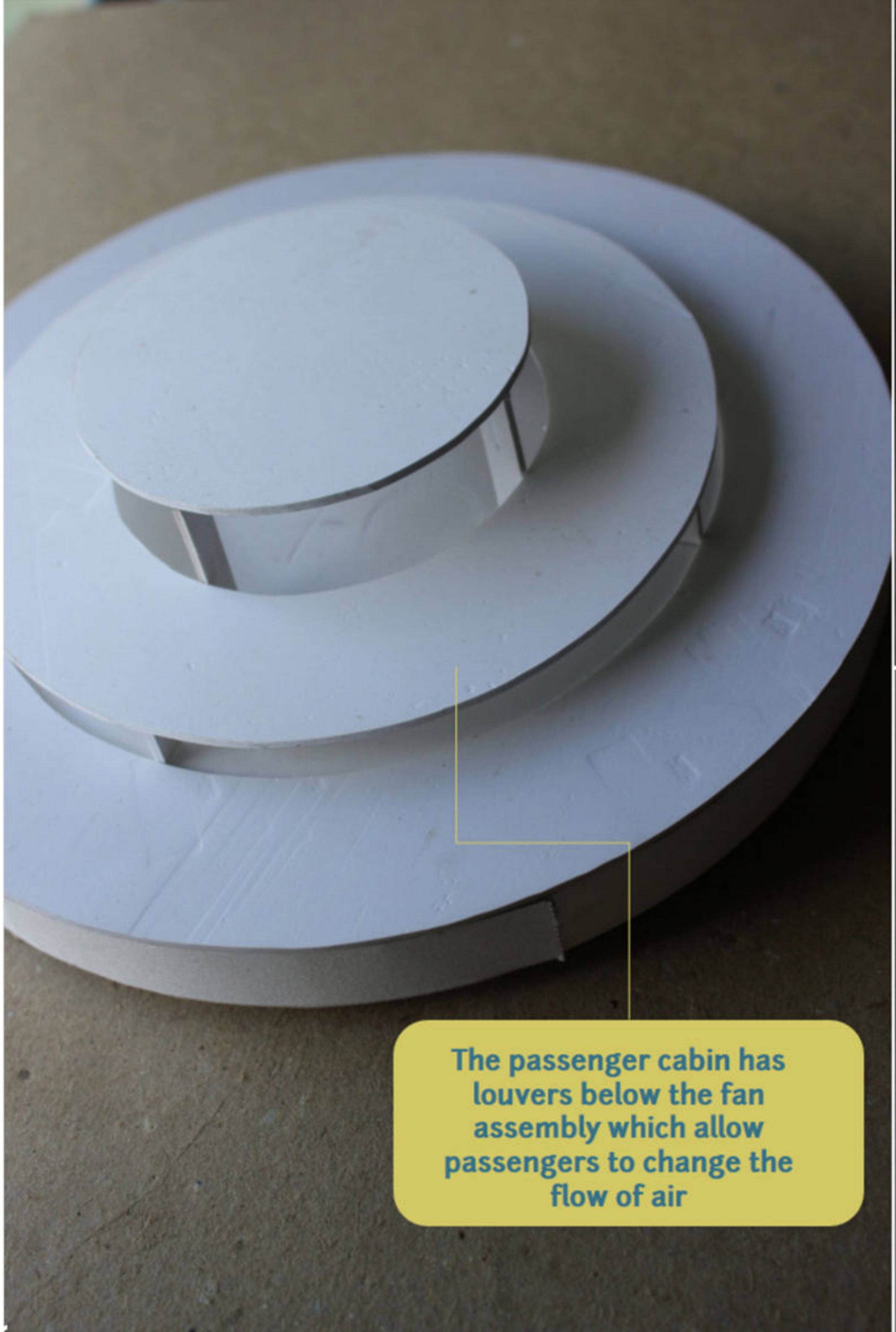
Passengers can control the airflow inside the cabin by means of louvres which can be adjusted as per their needs.

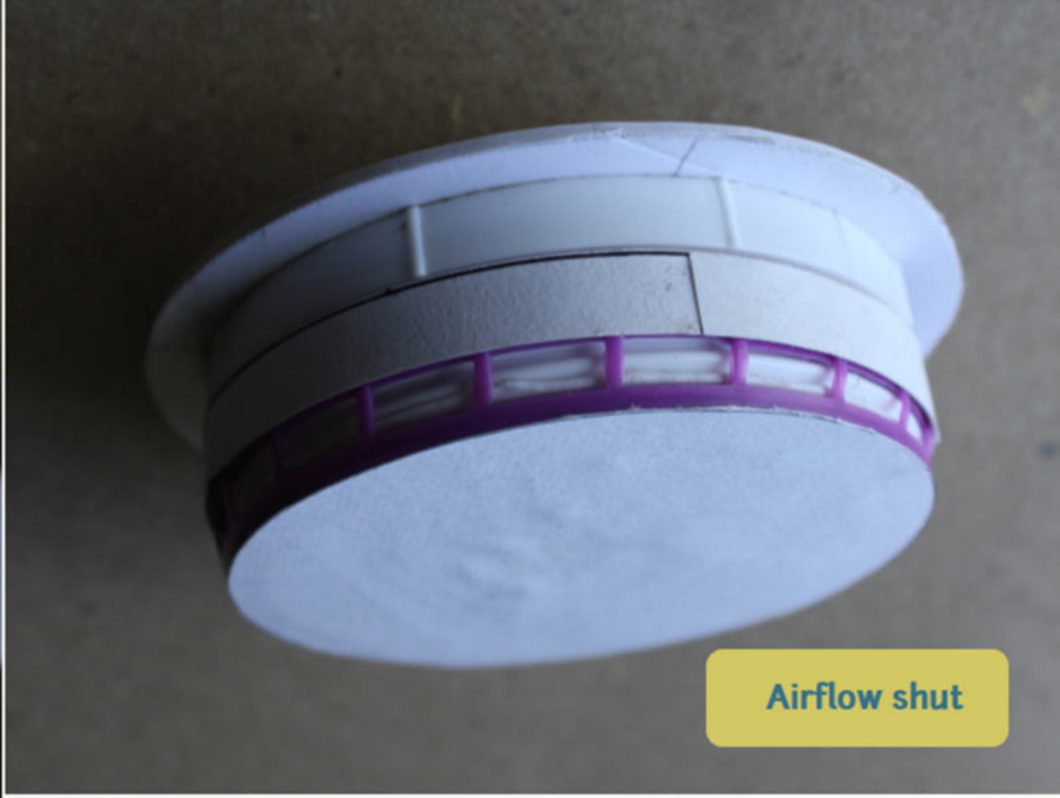


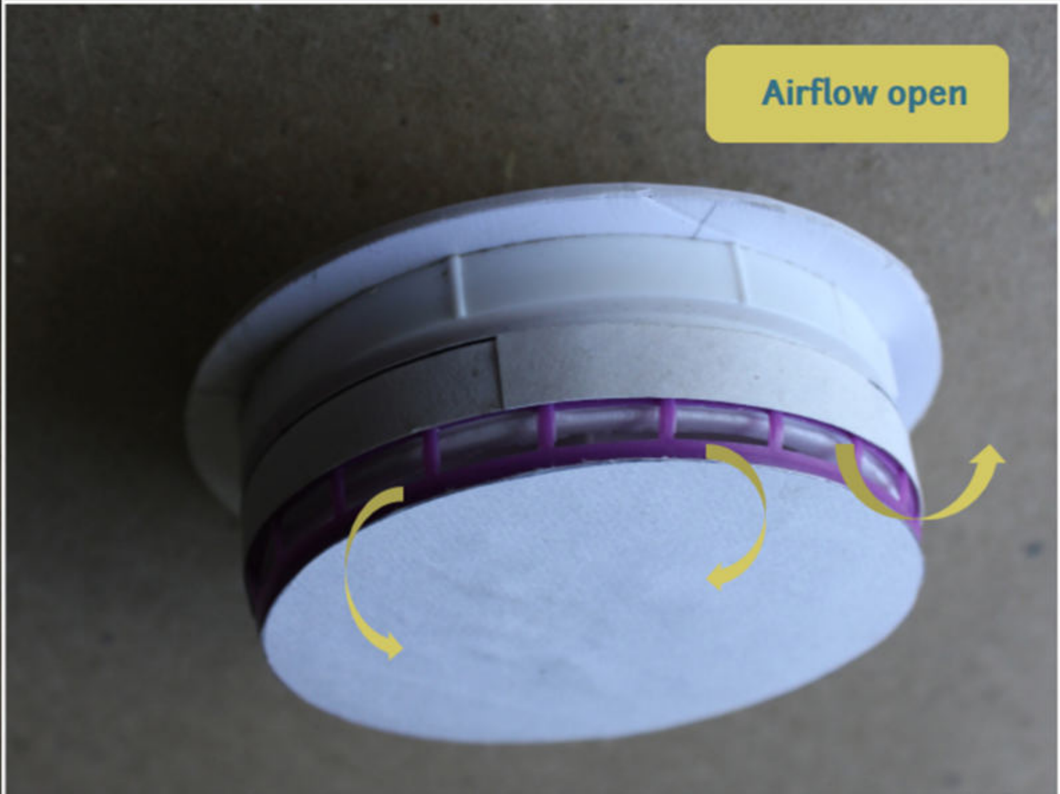
An individual wind catcher
Rain shielding
Filter panel

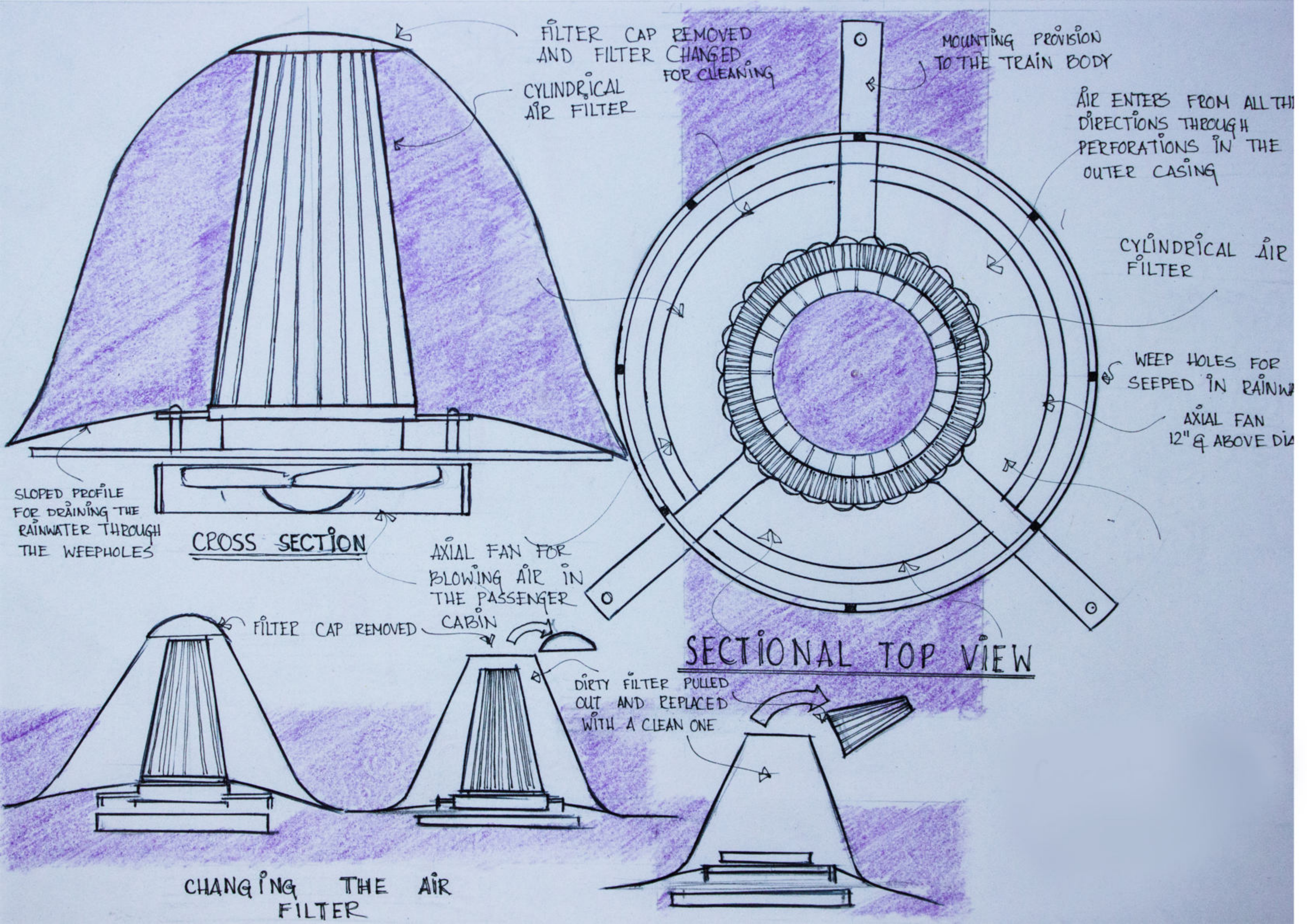

Filter fitting


This part connected to a fan assembly which flows air into the cabin


The passenger cabin has louvers below the fan assembly which allow passengers to change the flow of air

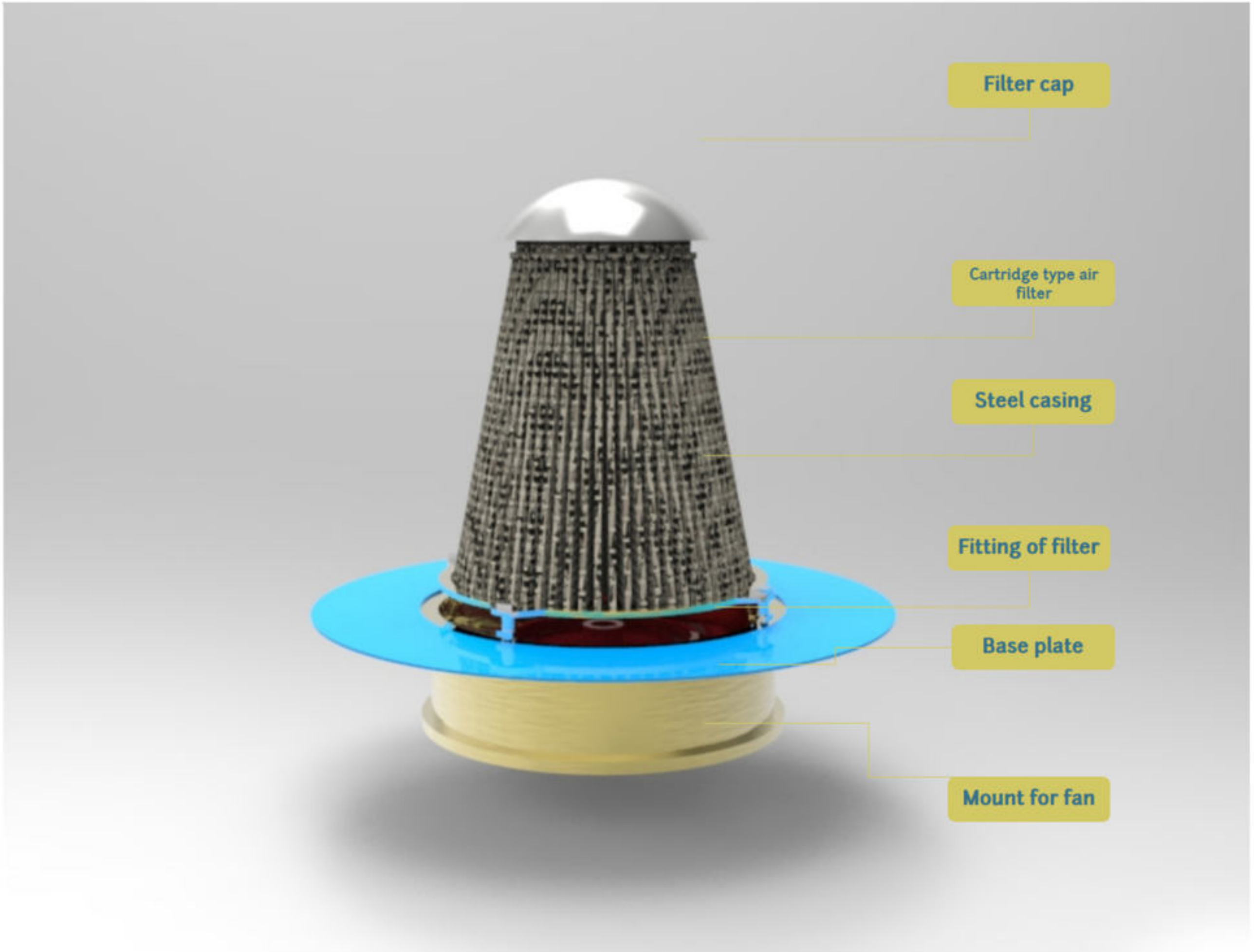

Airflow shut

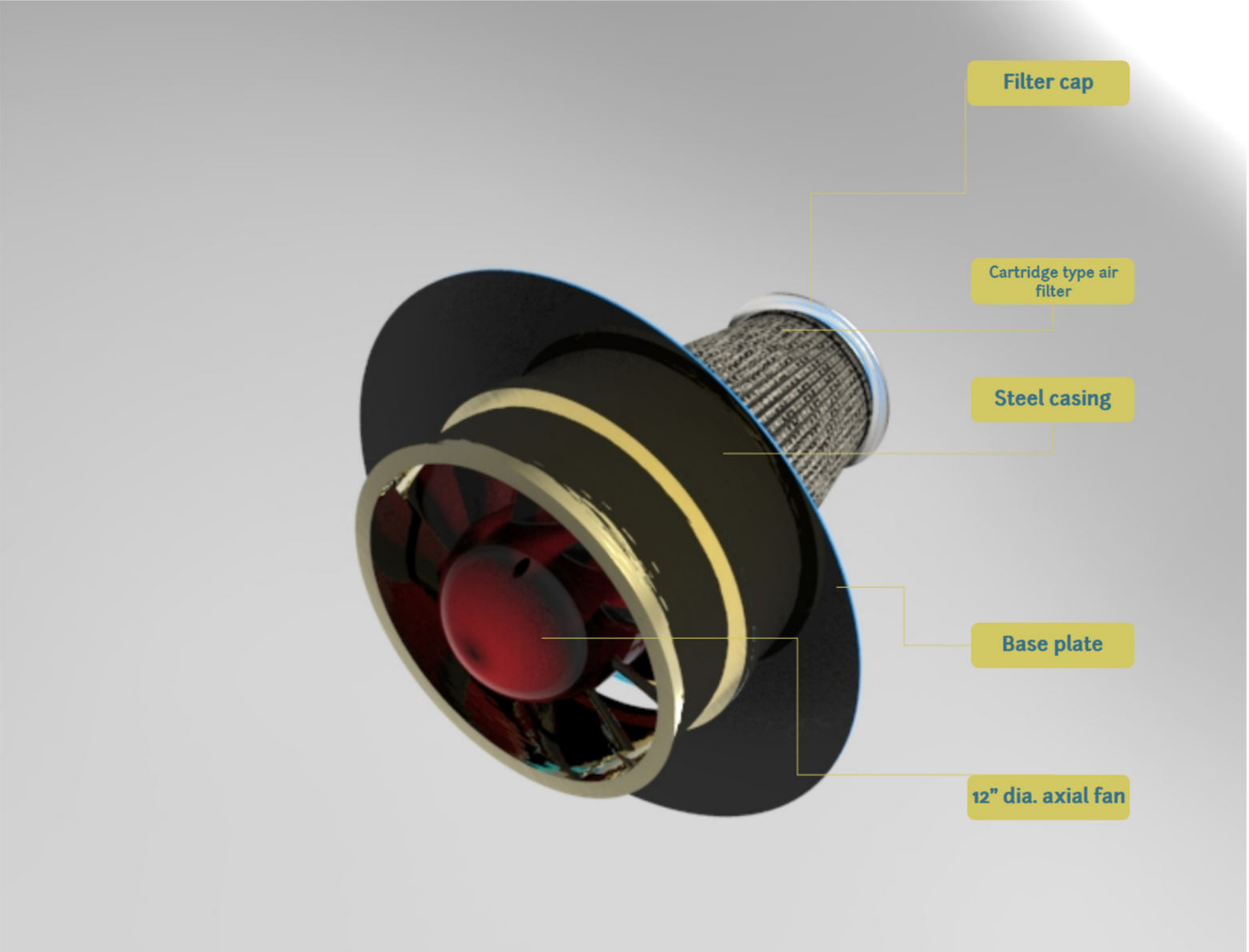

Airflow open

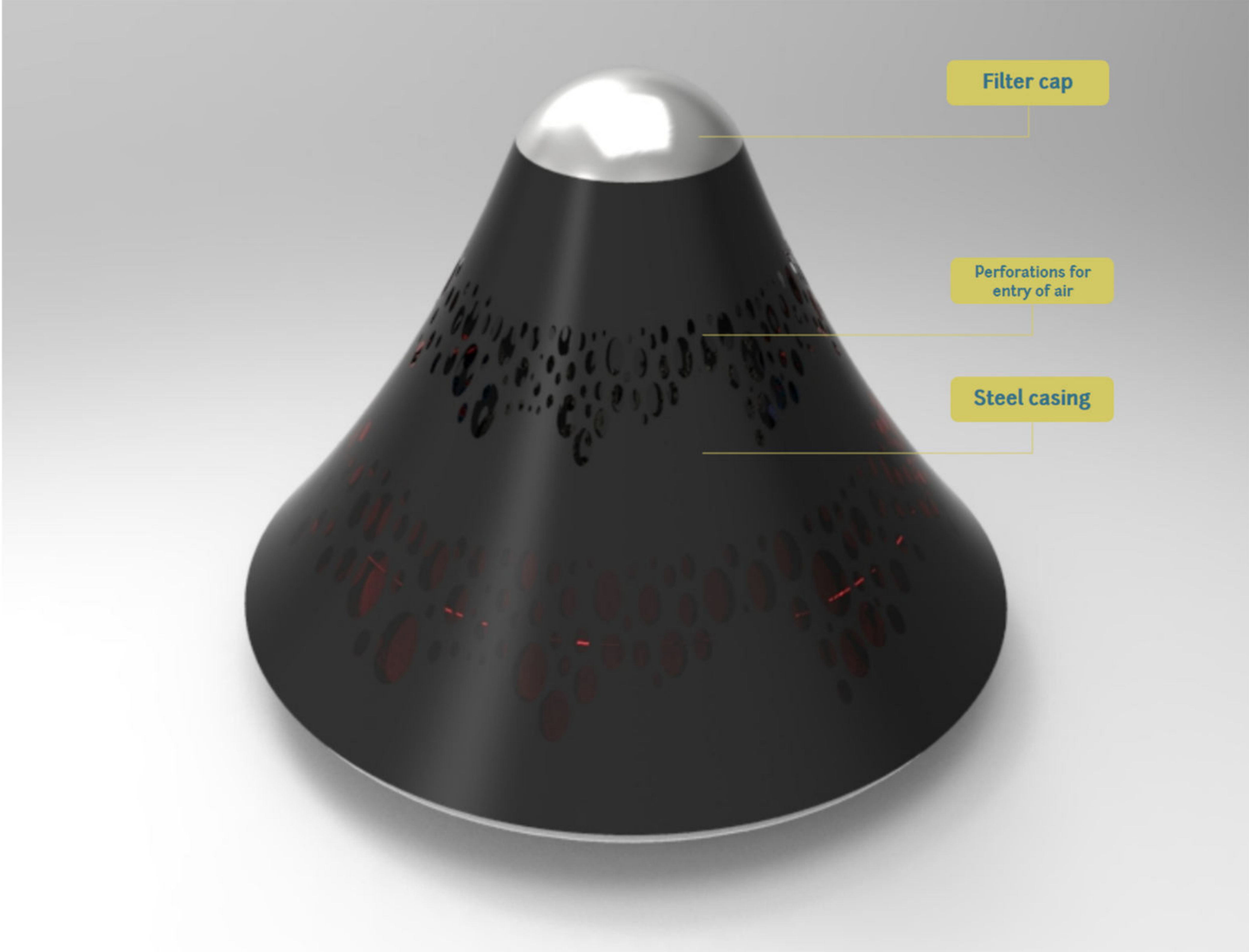

FILTER CAP REMOVED AND FILTER CHANGED FOR CLEANING
CYLINDRICAL AIR FILTER
SLOPED PROFILE FOR DRAINING THE RAINWATER THROUGH THE WEEPHOLES
CROSS SECTION
AXIAL FAN FOR BLOWING AIR IN THE PASSENGER CABIN
MOUNTING PROVISION TO THE TRAIN BODY
AIR ENTERS FROM ALL THE DIRECTIONS THROUGH PERFORATIONS IN THE OUTER CASING
CYLINDRICAL AIR FILTER
WEEP HOLES FOR SEEPED IN RAINW
AXIAL FAN 12" & ABOVE DIA
SECTIONAL TOP VIEW
FILTER CAP REMOVED
DIRTY FILTER PULLED OUT AND REPLACED WITH A CLEAN ONE
CHANGING THE AIR FILTER

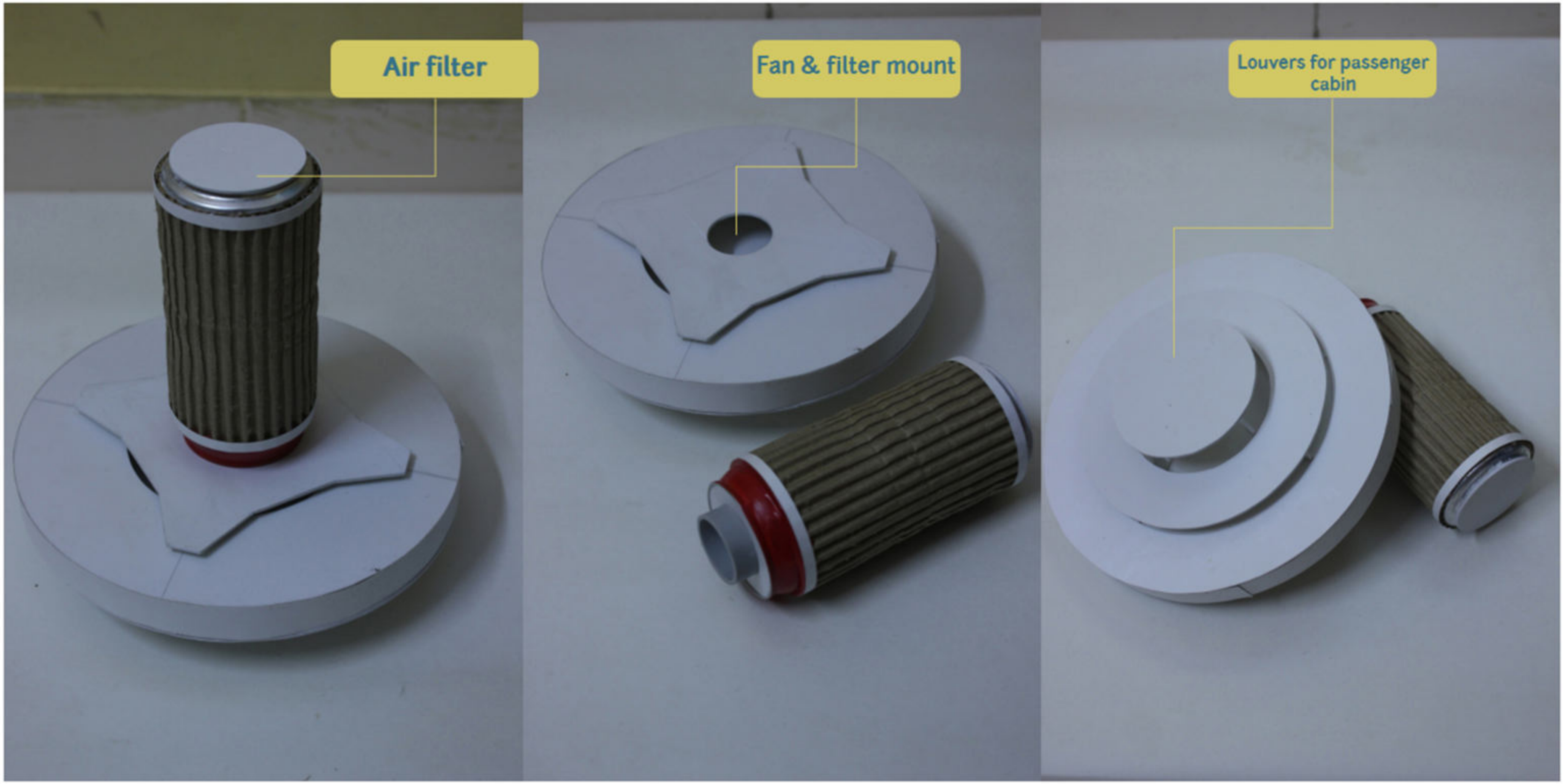
Option-2

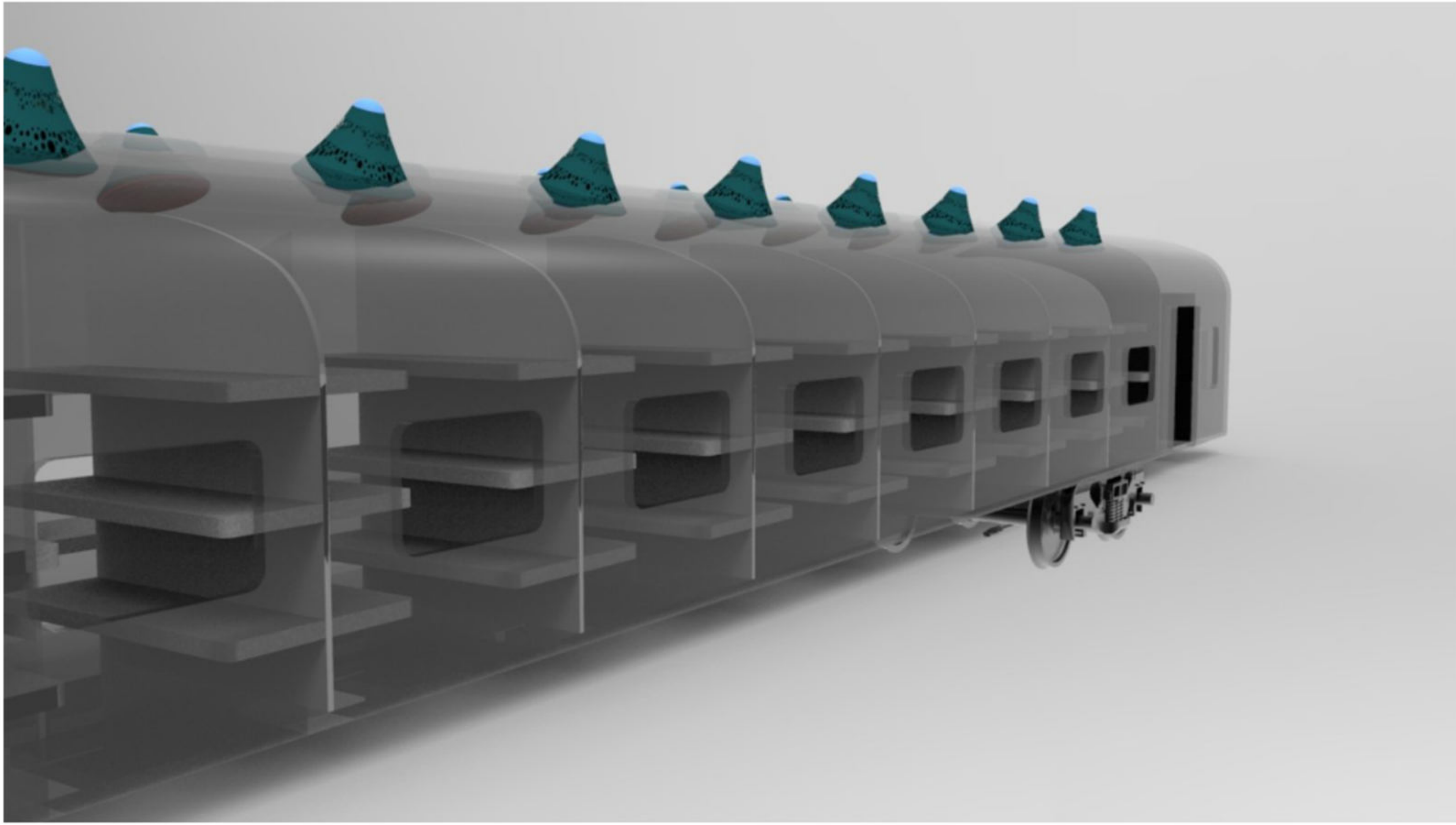
This option of the windcatcher uses an electrostatic filter mounted in a chamber as shown in the drawing. The filter is kept parallel to the direction of the winds. Perforations in the casing of the chamber allows air to enter from all directions irrespective of which direction the train is moving. To prevent seepage of rainwater into the passenger cabin a plate having a curved profile is added just below the air filter to drain out any water seeped in through weep holes located at the base. Below the plate is an axial fan 12 inch to 16 inch diameter. The fan supplies fresh filtered air into the passenger cabin at all times.



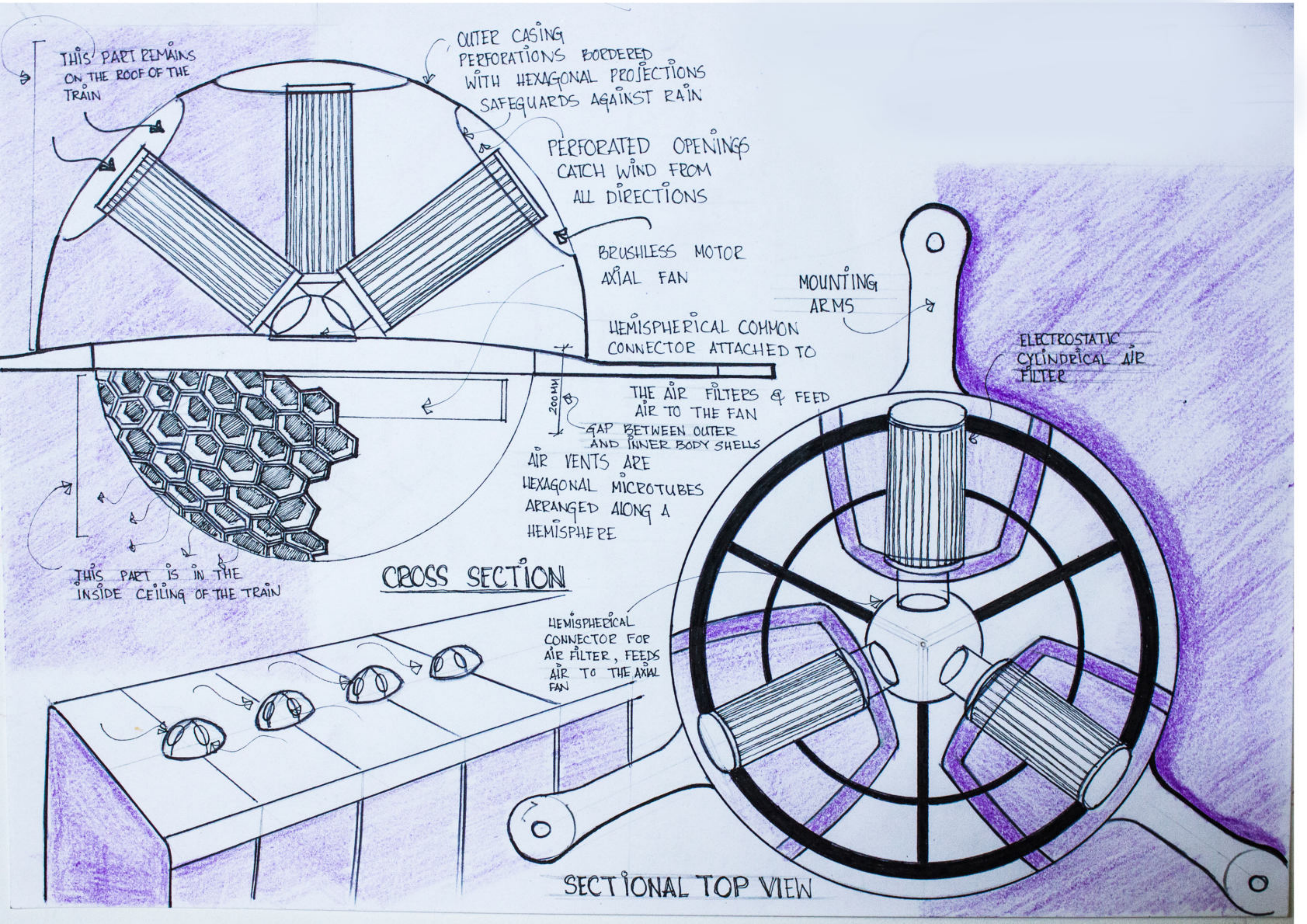

Filter cap
Cartridge type air filter
Steel casing
Base plate
12” dia. axial fan


Filter cap
Perforations for entry of air
Steel casing


Air filter
Fan & filter mount
Louvers for passenger cabin



Wind catching units placed on the roof of the train above every passenger partition

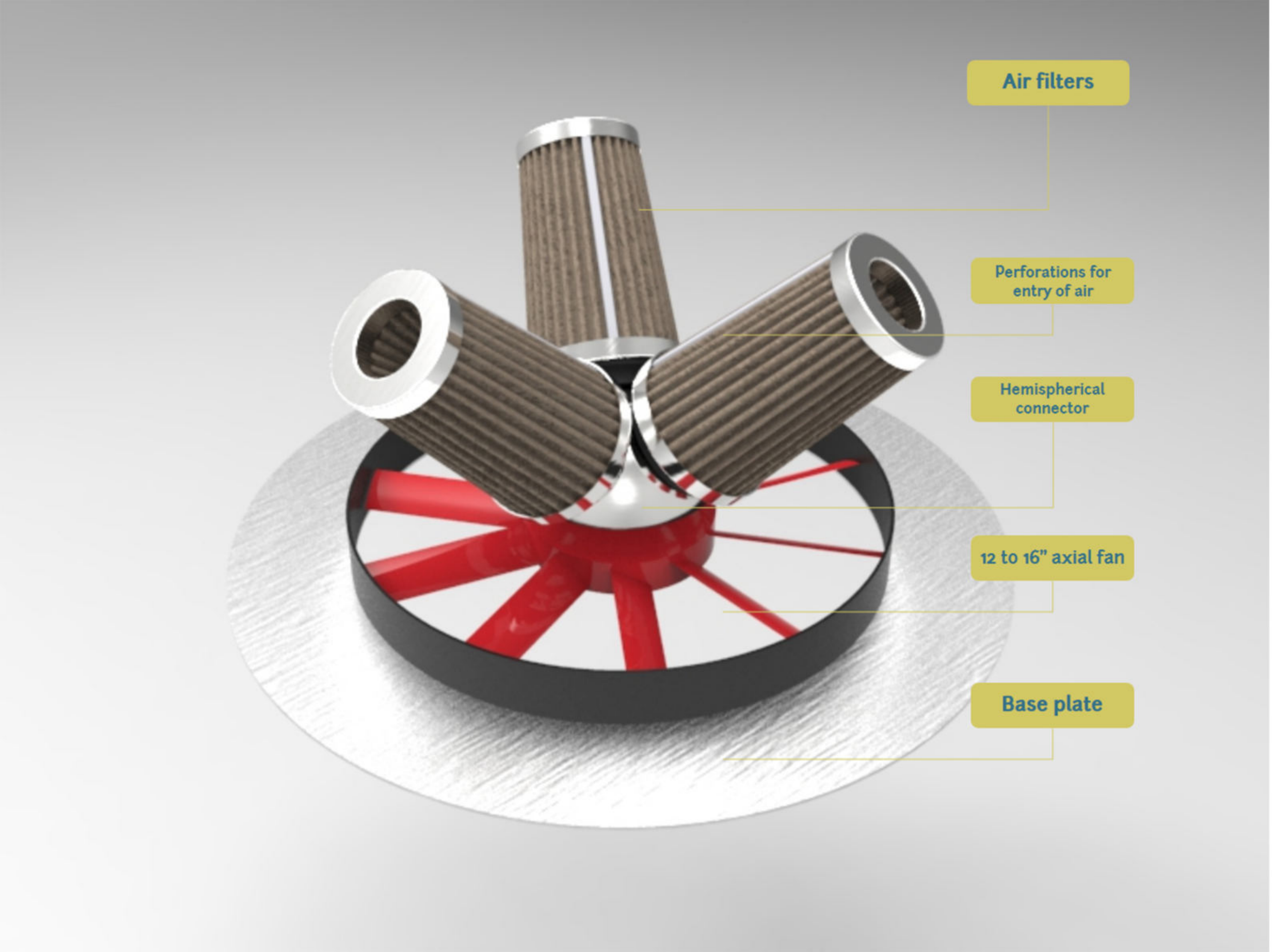


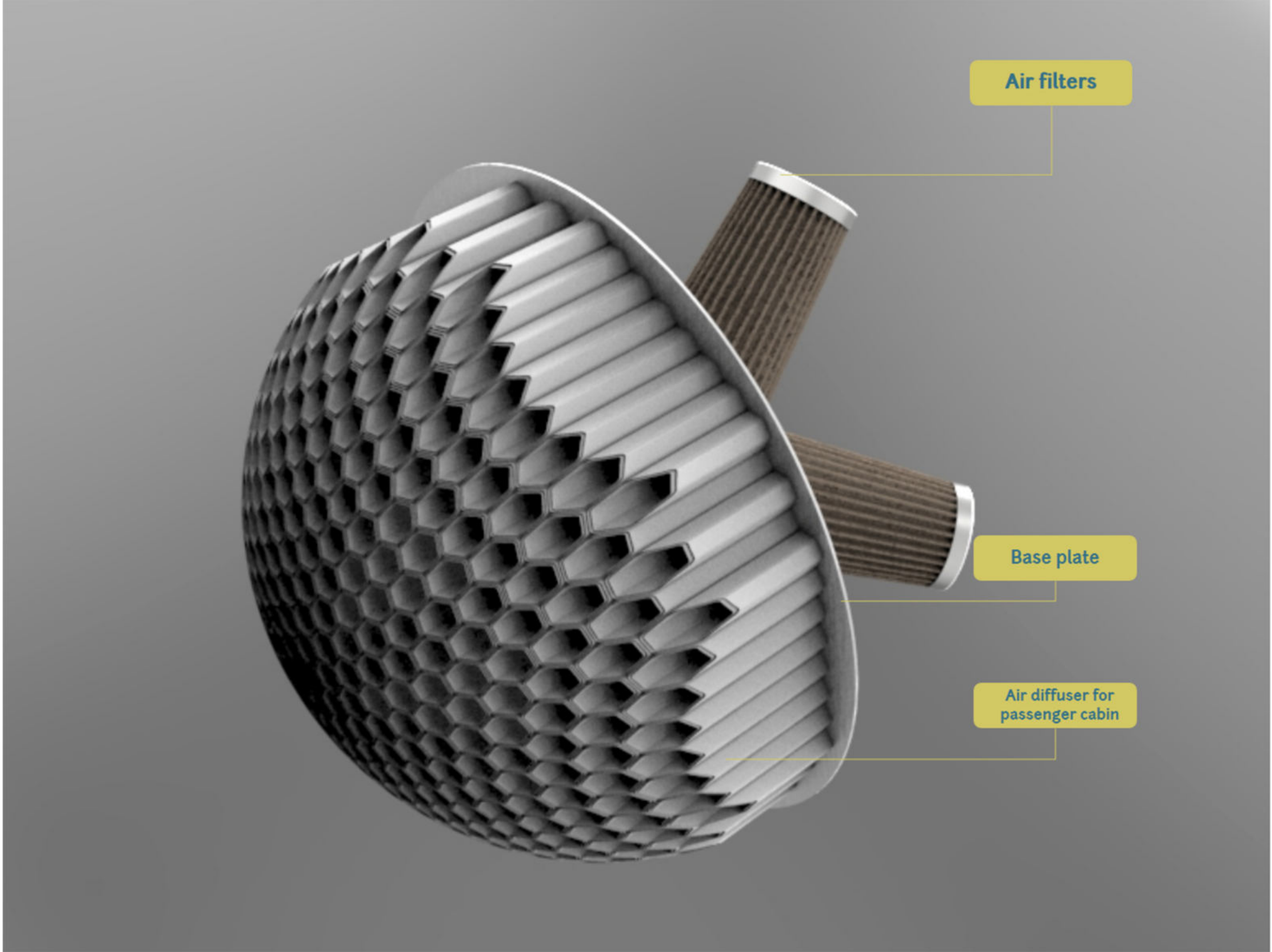
THIS PART REMAINS ON THE ROOF OF THE TRAIN
OUTER CASING PERFORATIONS BORDERED WITH HEXAGONAL PROJECTIONS SAFEGUARDS AGAINST RAIN
PERFORATED OPENINGS CATCH WIND FROM ALL DIRECTIONS
BRUSHLESS MOTOR AXIAL FAN
HEMISPHERICAL COMMON CONNECTOR ATTACHED TO THE AIR FILTERS & FEED AIR TO THE FAN
200 MM
GAP BETWEEN OUTER AND INNER BODY SHELLS
AIR VENTS ARE HEXAGONAL MICROTUBES ARRANGED ALONG A HEMISPHERE
THIS PART IS IN THE INSIDE CEILING OF THE TRAIN
CROSS SECTION
MOUNTING ARMS
ELECTROSTATIC CYLINDRICAL AIR FILTER
HEMISPHERICAL CONNECTOR FOR AIR FILTER, FEEDS AIR TO THE AXIAL FAN
SECTIONAL TOP VIEW

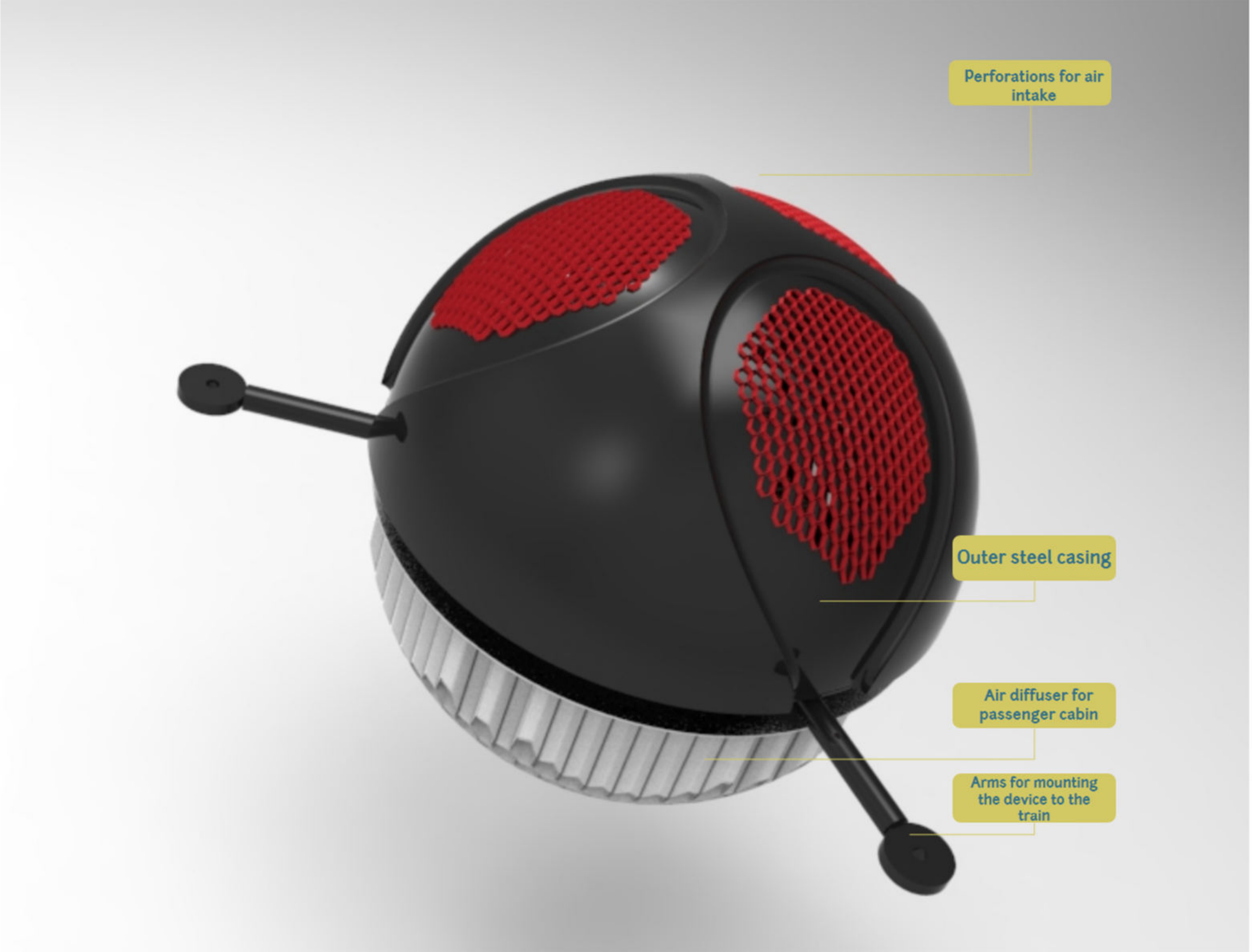
Option-3

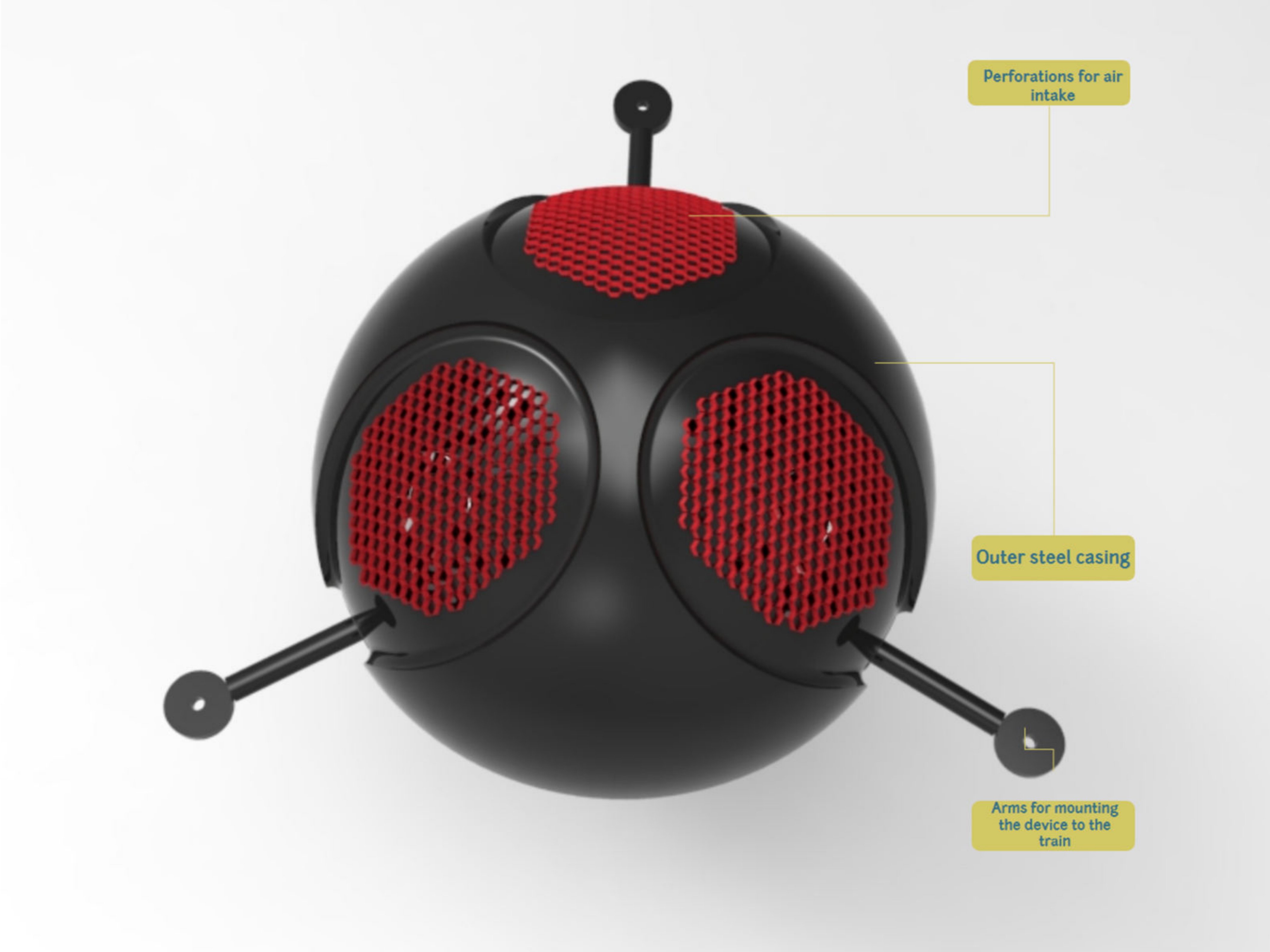
This option houses three electrostatic cylindrical filters in the chamber placed at the roof of the train. The three filters individually catch air from different directions and is connected to a hemispherical connector which feeds the collected air into an axial fan below.. This option filters more dust as the filters are perpendicular to to the direction of the wind. Air is released into the passenger cabin by means of an hemispherical mesh to distribute the air evenly without direct force yet without obstructing the flow

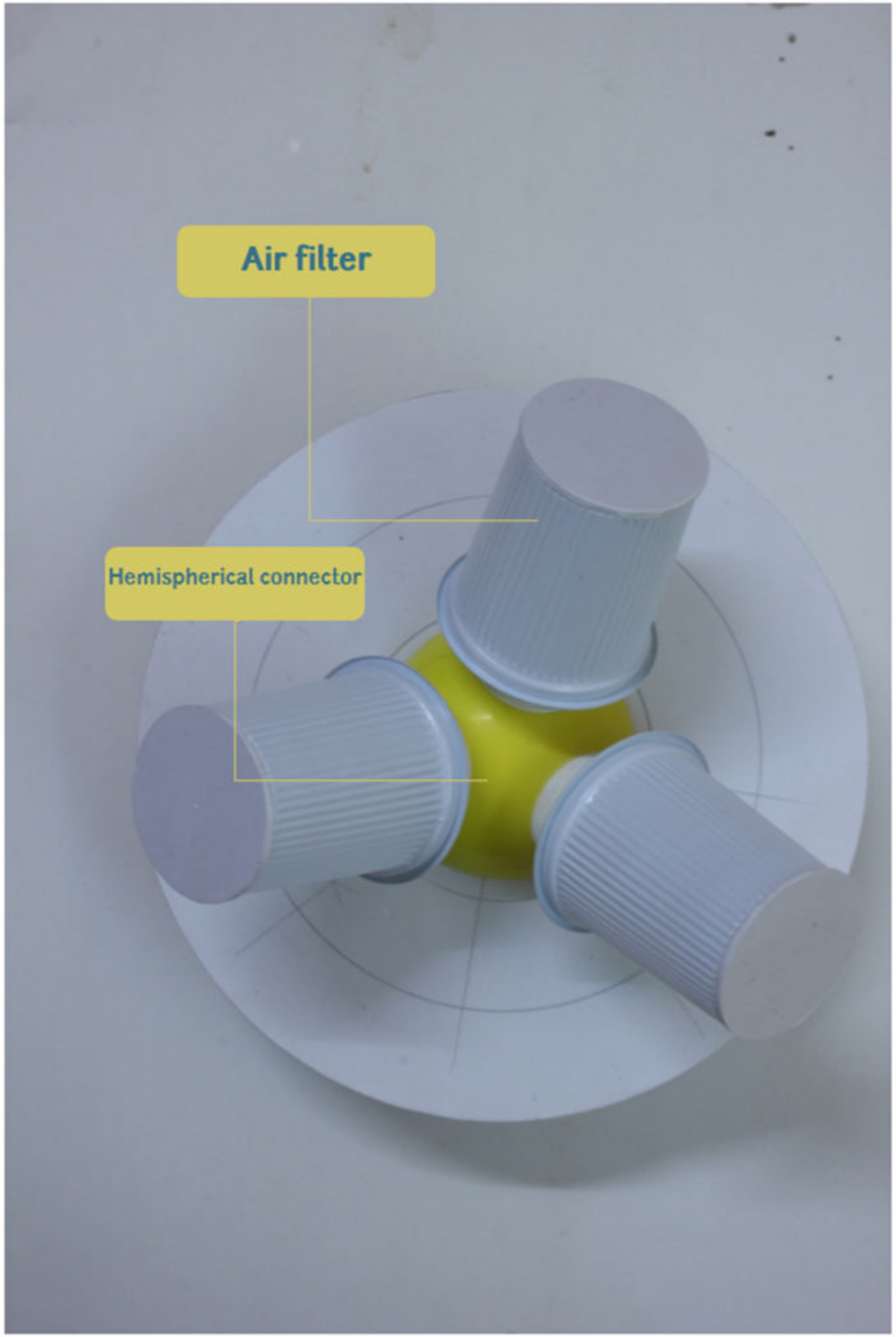
Similar to the earlier option a plate of curved profile is provided to allow drainage of seeped in water and not enter into the fan asembly. Axial fans of 12 inch or 16 inch diameter may be used depending on the quality of the airflow.

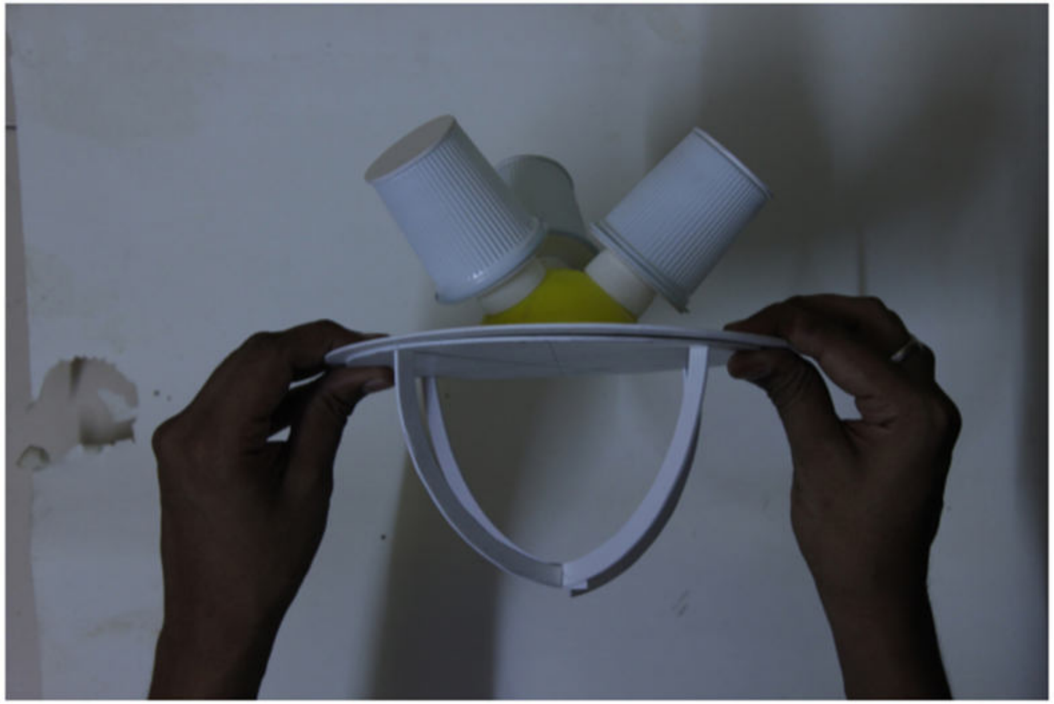

Air filters
Perforations for entry of air
Hemispherical connector
12 to 16” axial fan
Base plate


Air filters
Base plate
Air diffuser for
passenger cabin


Perforations for air intake
Outer steel casing
Air diffuser for passenger cabin
Arms for mounting the device to the train


Perforations for air intake
Outer steel casing
Arms for mounting the device to the train


Air filter
Hemispherical connector



Final concept

As stated earlier two systems of ventilation and cooling for the passenger compartment has been discussed both having its own positives and negatives. But by looking into the Concept 2 which offers evaporative cooling and wind catcher units to increase ventilation, it has been chosen as the final concept.
Depending on the zone the train is travelling and the outside temperature conditions, the evaporative cooler can be overriden manually to control the ambient conditions. When cooling is not required, the blowers still run without pumping water, and when facilitated by the wind catchers it provides the airyness as the open windows.
The option 3 for the windcatchers is better suited for filtering dust, as the filters are perpendicular to the direction of the airflow but for maintenance issues considering the filters are cleaned after every trip, option 2 is better. Providing electrostatic cartridge filters enable them to work for months in dusty conditions although a cleanup after every trip is recommended when the train halts at the yard for cleaning and maintenance. The filters are easily accesible for the maintenance crew at the top of the roof of the train. The advantages and disadvantages of both the concepts are discussed to summarize the pros and cons of both system and the final system is represented.

The final concept, advantages and disadvantages

The advantages of the final concept are highlighted aside which determines the factors considered for choosing the final concept. The represention of this concept as a whole implemented on a railway coach is shown later.

Advantages

Lower installation and running cost compared to air conditioners.

High air flow throughout the passenger cabin

Ease of maintenance, the mechanical parts are the fans and the pumps

Can be manually overridden depending on the climatic condition outside

The high flow rate throughout reduces the “age of air” in the cabin

Cooling can perform brilliantly in hot dry climates such as parts of north and central India

Passengers have the option to control the airflow from the wind catchers depending upon conditions outside.

Residual water from the cooler can be used for flushing toilets

Passenger partition separated from the toilets and fresh air source is from the top of the train. No obnoxious odours waft inside the passenger area.

Passenger partition separated from the toilets and fresh air source is from the top of the train. No obnoxious odours waft inside the passenger area.

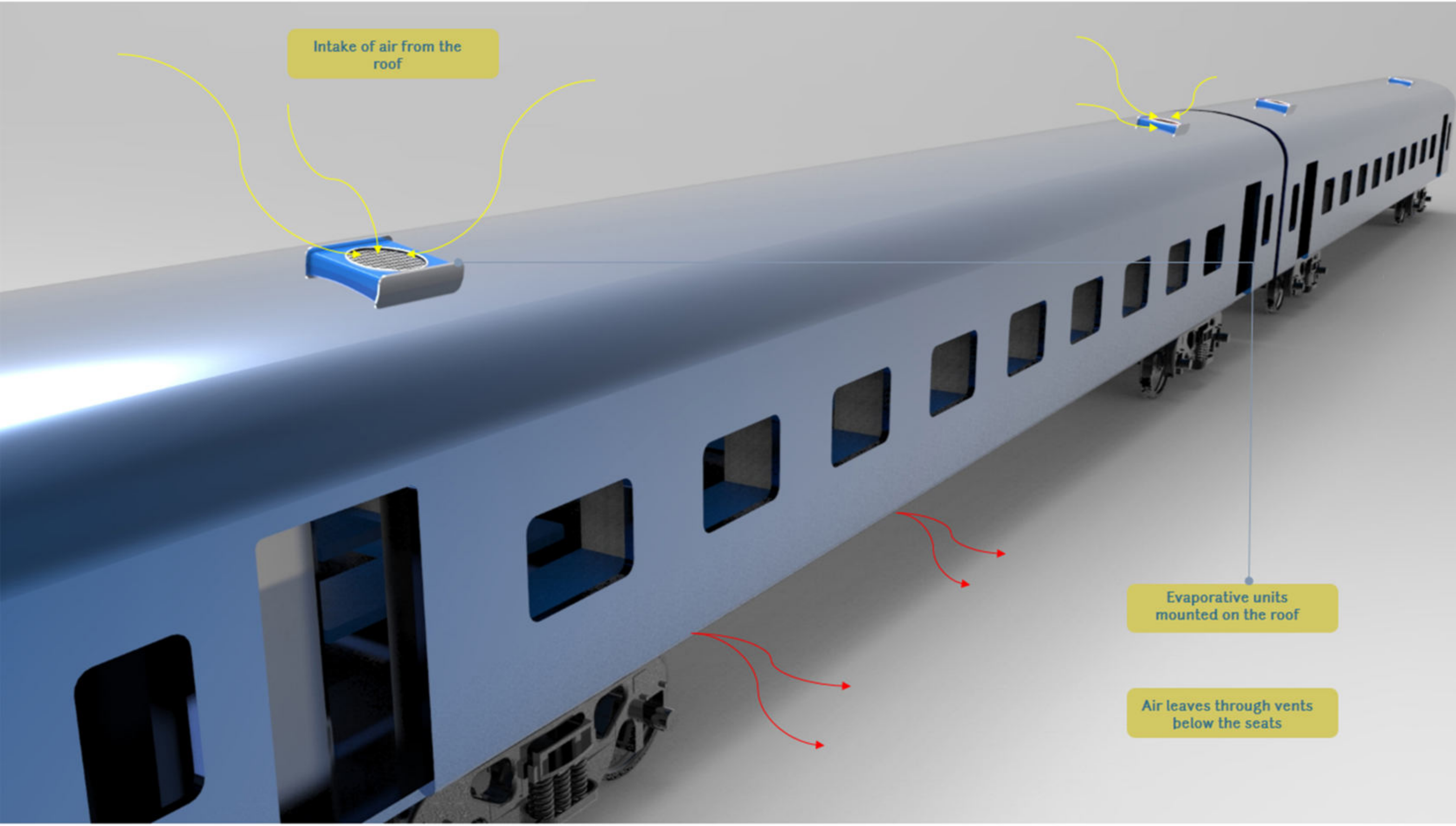
Disadvantages

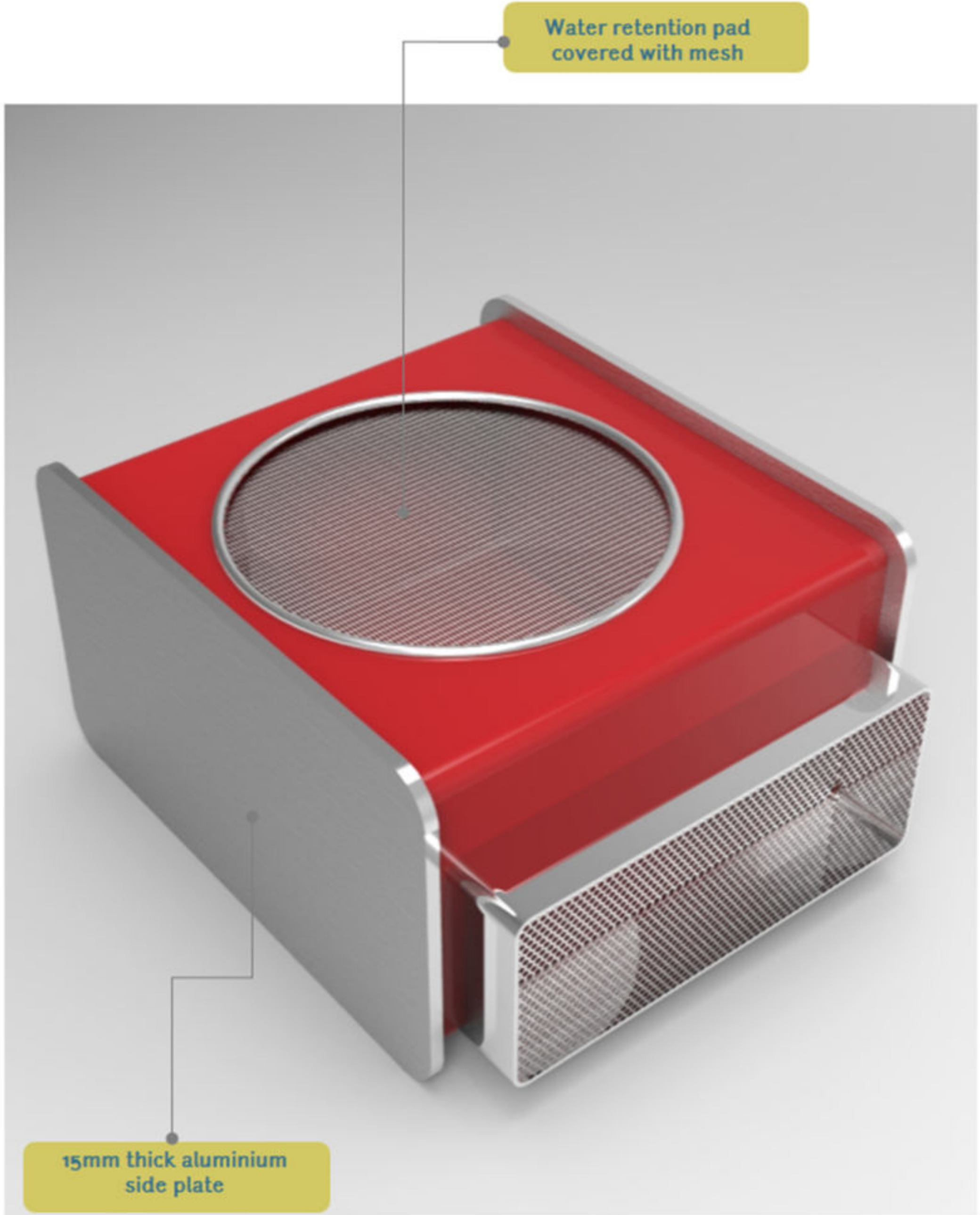
Foul smell can arise if the water retaining pads are not replaced timely, which even forms the dwelling for moulds and mildew.

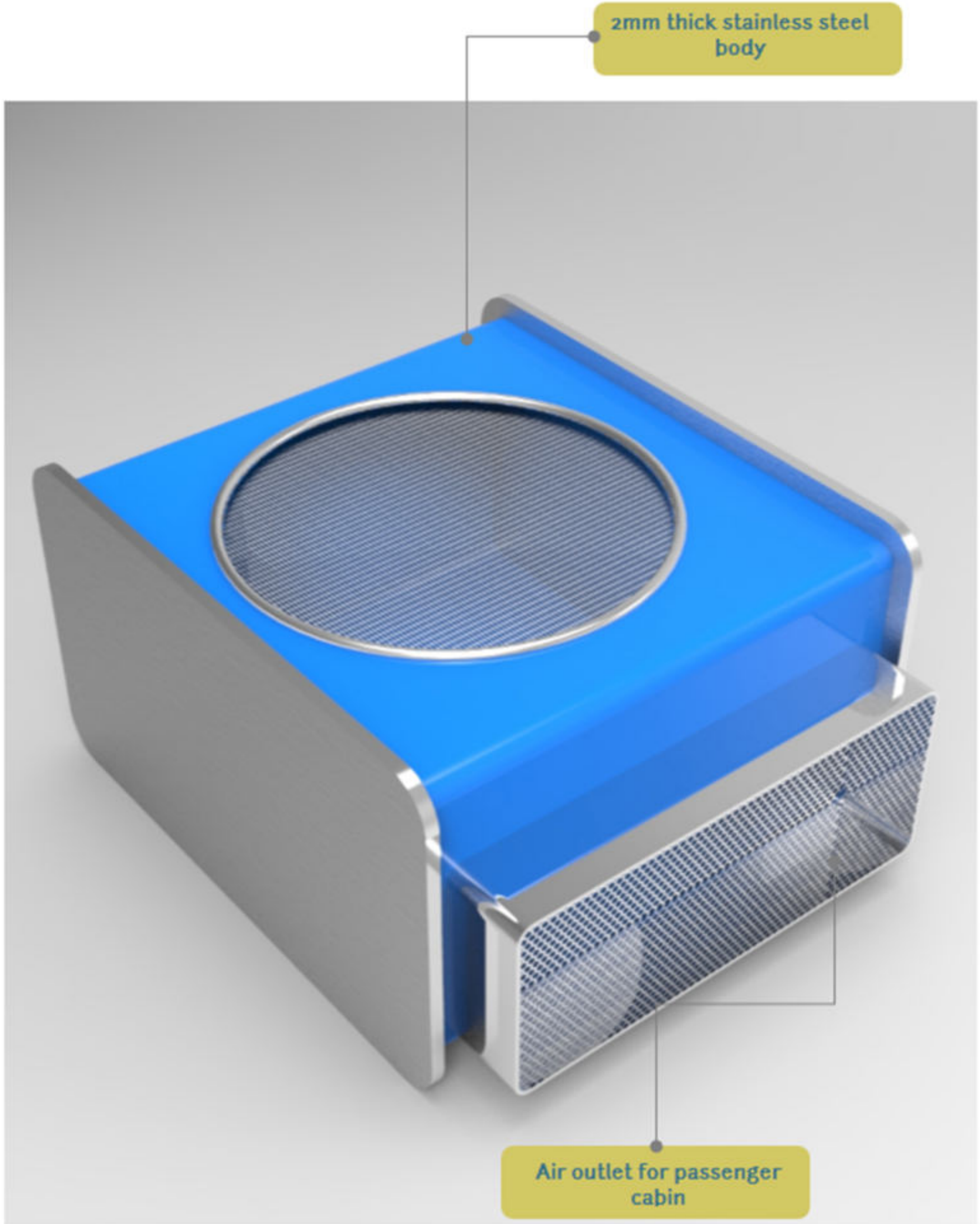
In case of humid climates cooling needs to be powered off, as it can increase humidity drastically and cause discomfort and accumulation of moisture.

Unclean coolers can form breeding grounds of mosquitoes, however this problem will be resolved as maintenance will happen after every trip.

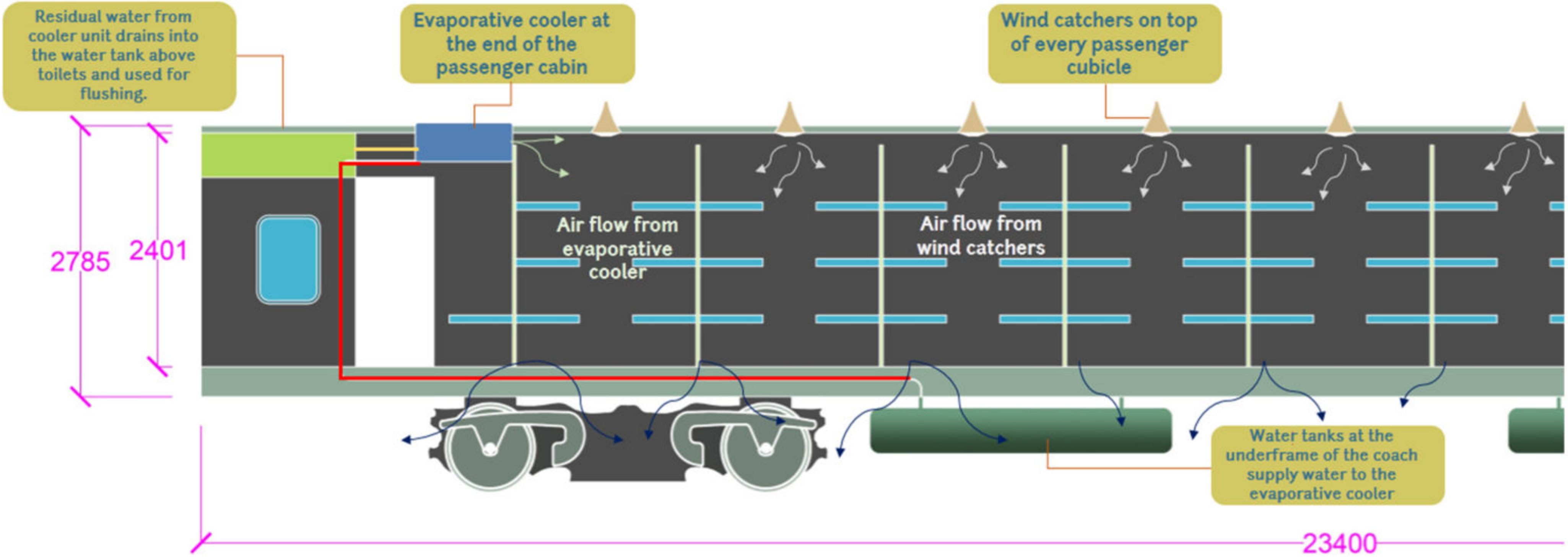
Excessive water consumption if the units are run continuously.

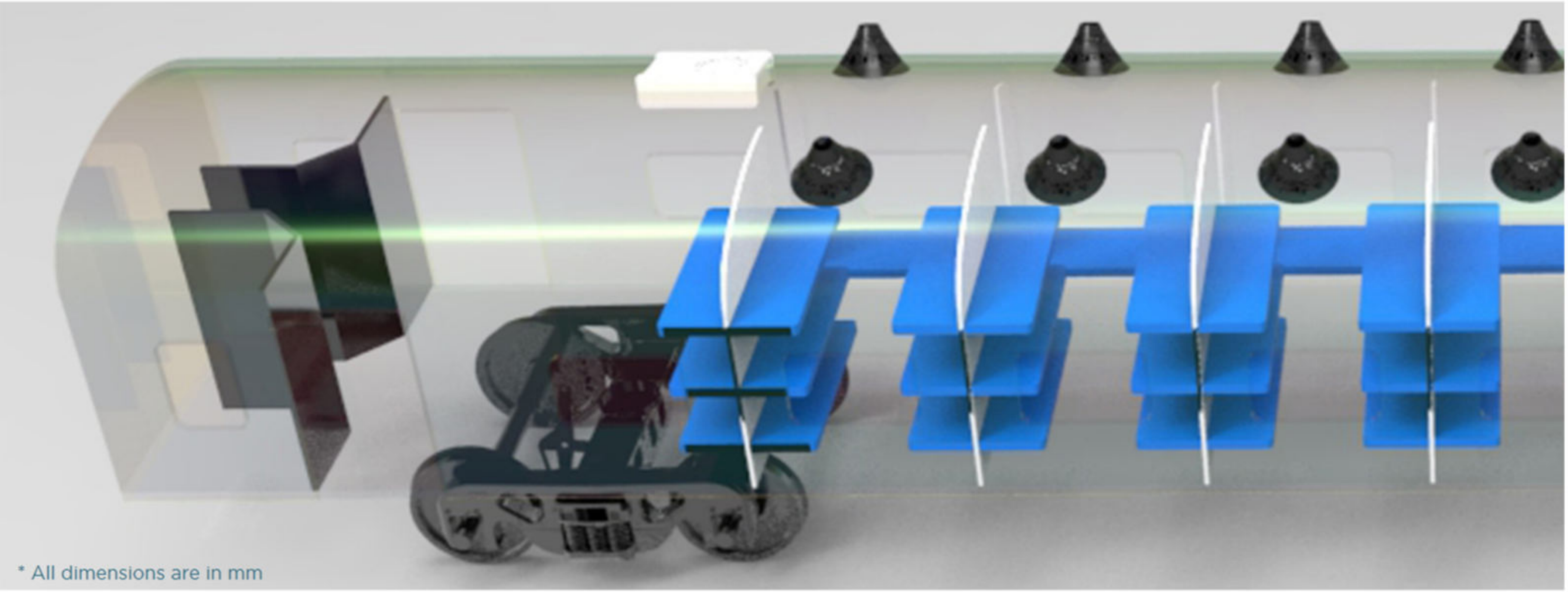

Intake of air from the roof
Evaporative units mounted on the roof
Air leaves through vents below the seats



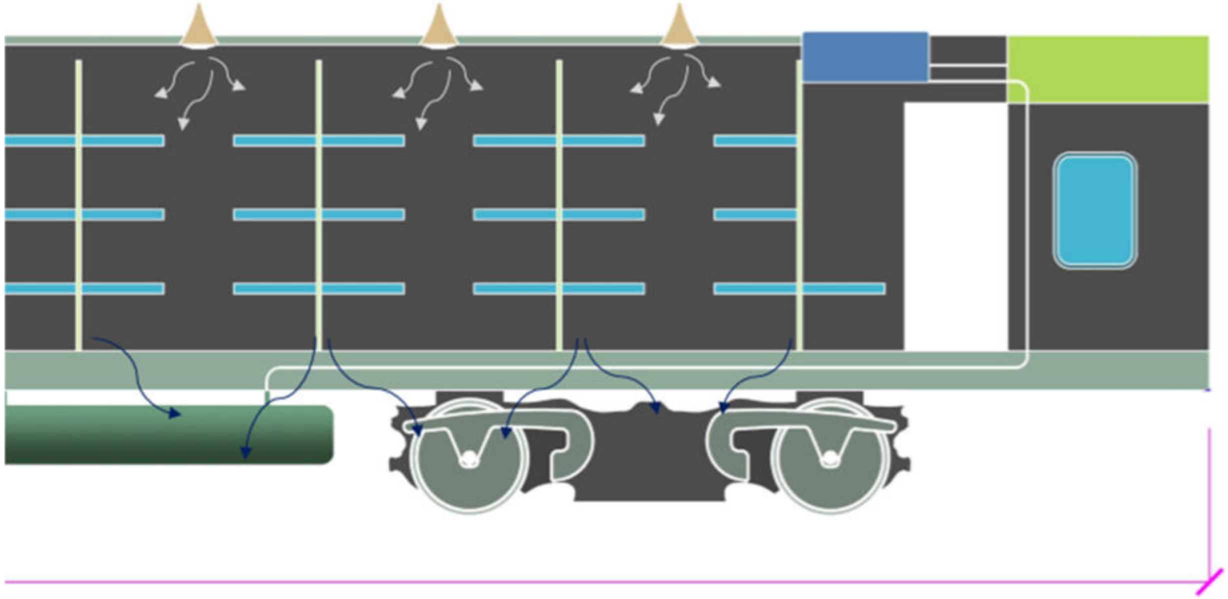


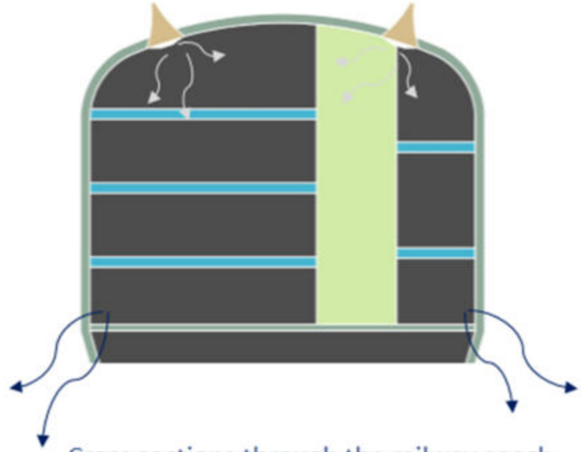
Option for the evaporative cooler, mounted on the train coach in a colour scheme corresponding to LHB coaches.



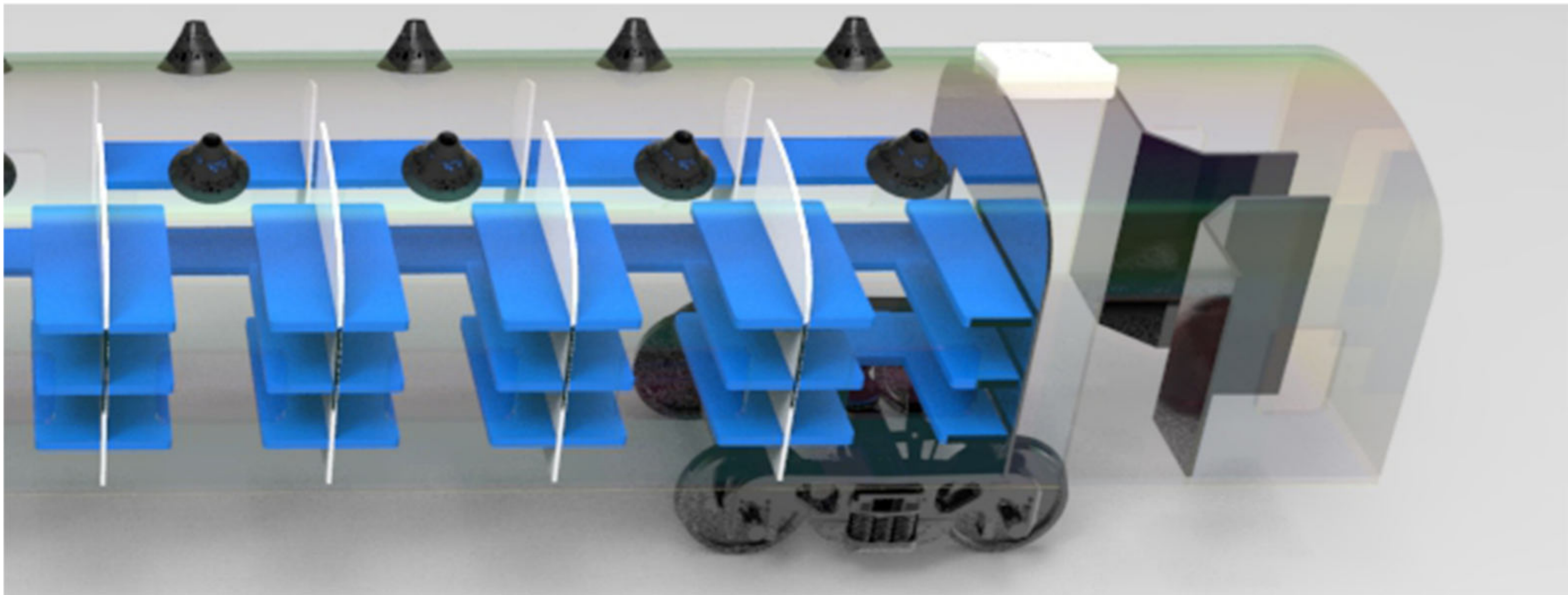


* All dimensions are in mm





Cross sections through the railway coach showing the layout of the ventilation system

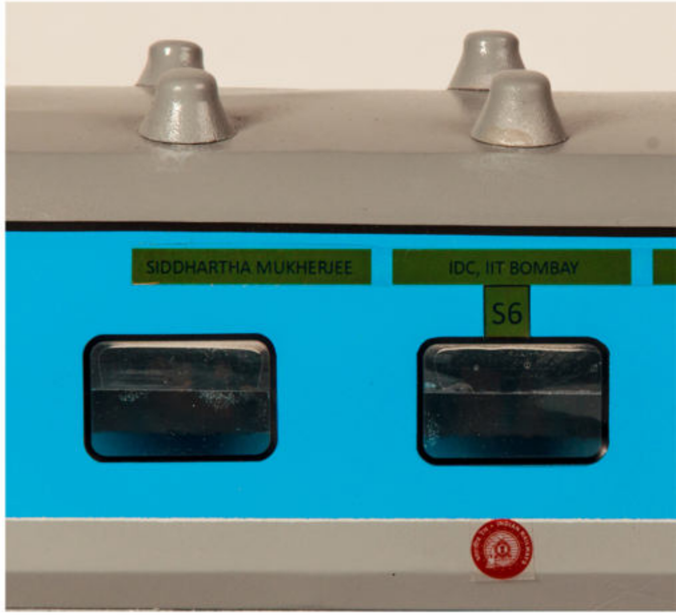


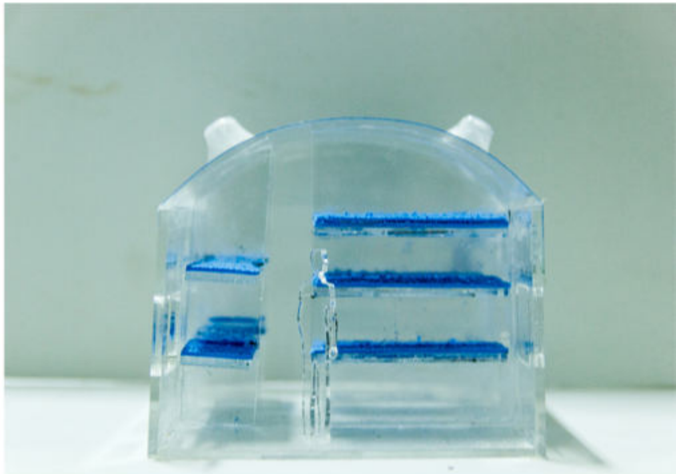
Final model

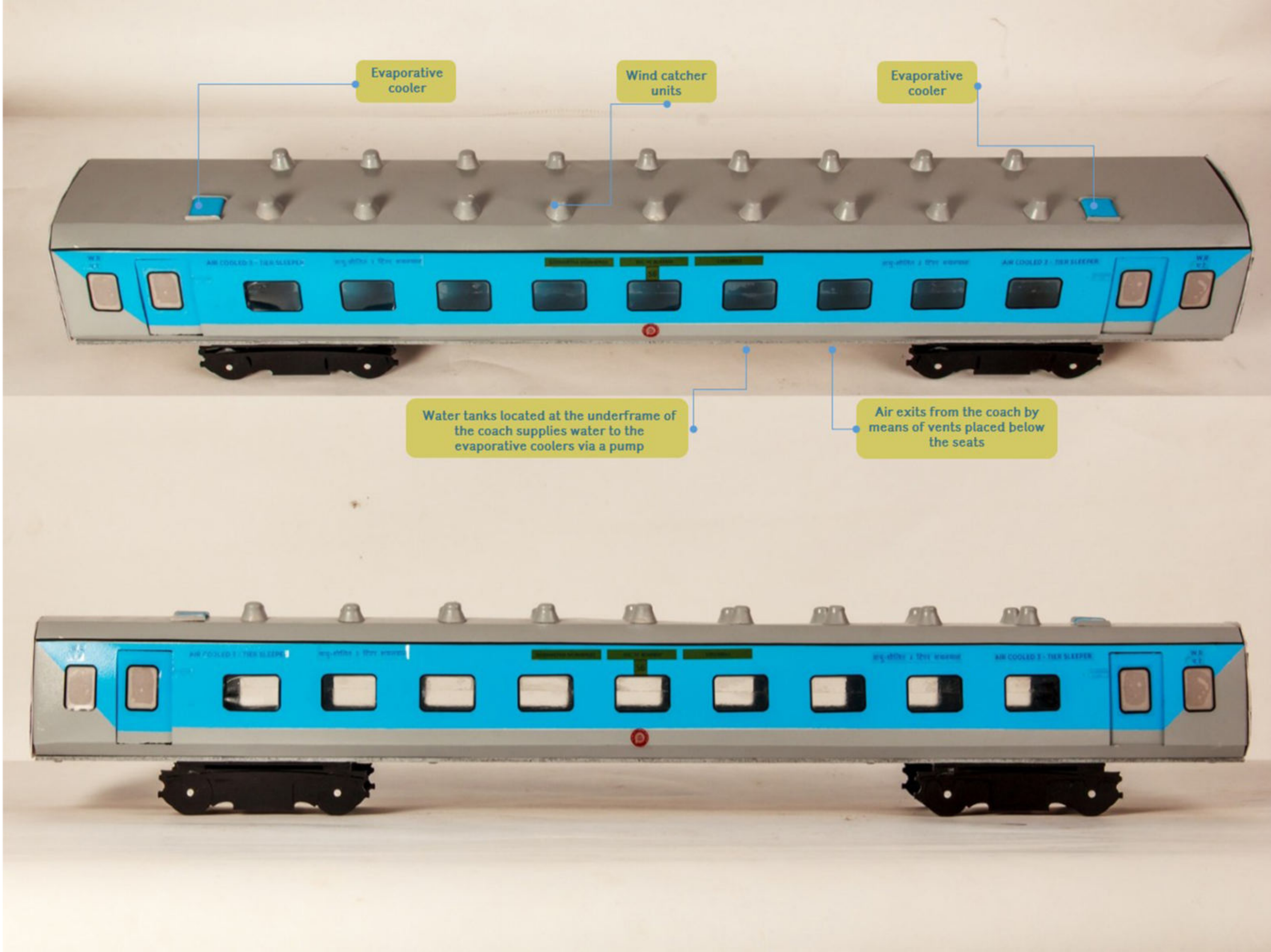
The models aside shows the cut section of a passenger cabin showing the windcatching unit at the top as well as the array of wind-catching units and the evaporative cooler units arranged on the roof of the train.

The wind catching units are the units which work continuously on the power generated by the running train and provide ventilation throughout the passenger cabin.

The evaporative cooler units are the units which cool the ambient temperature when needed and can be manually overridden to work alongwith the windcatcher units or turned off when not needed. It's not feasible for performing in humid climates but performs well in case of a hot and dry climate predominant throughout Central and North India.






Evaporative cooler
Wind catcher units
Evaporative cooler
Water tanks located at the underframe of the coach supplies water to the evaporative coolers via a pump
Air exits from the coach by means of vents placed below the seats

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