New system or method of tunnel ventilation

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Introduction

Suggested New System or Method for Tunnel Air Ventilation

BACKGROUND OF THE INVENTION

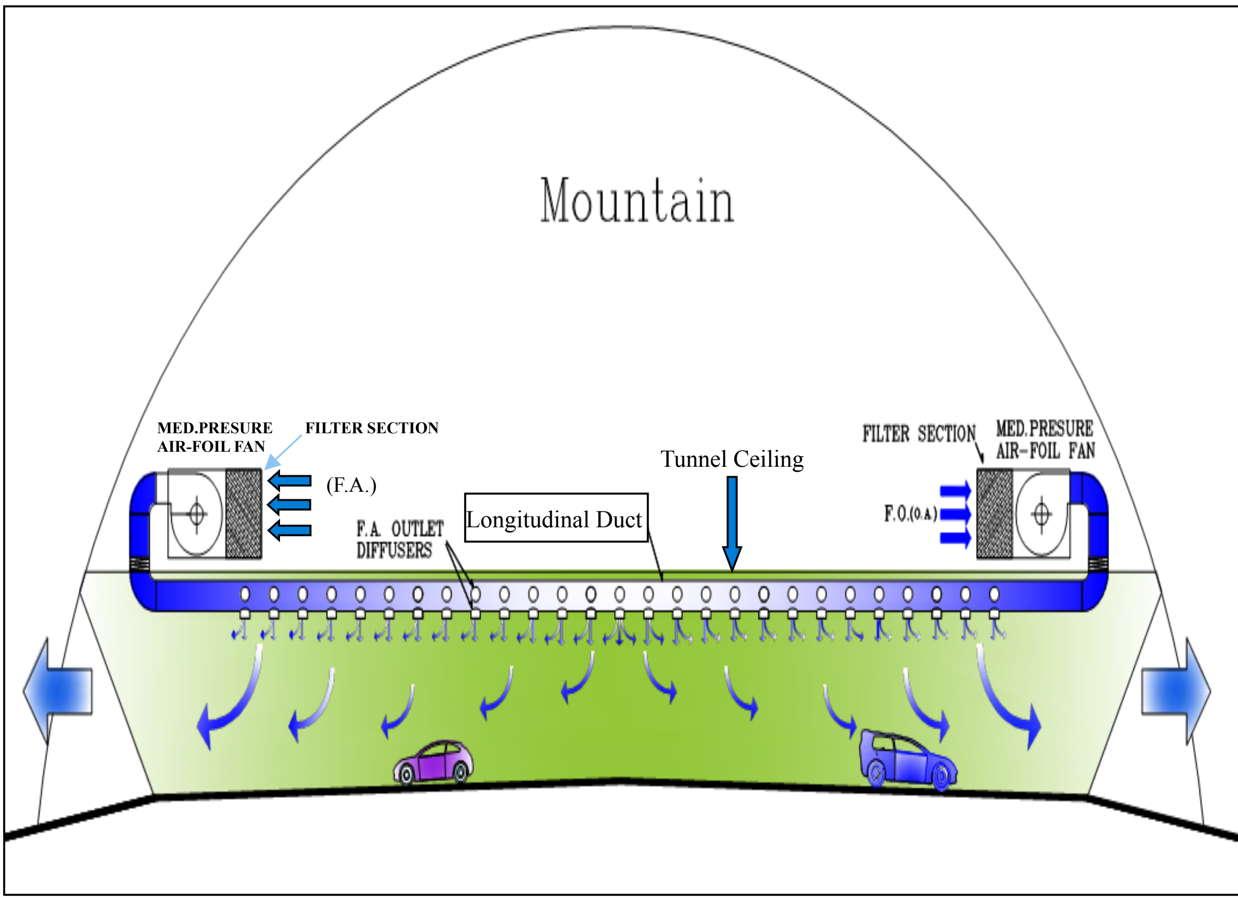
For the past few decades, the important subject of the tunnel air ventilation (for elimination or minimizing the internal pollutions) has been mostly done by similar conventional methods. That is, the current standards of operation have remained the same and intact. This made the illusion that there were no other ways to solve this problem. The basis of the named method is (and has been) using the ceiling type jet fans, using precise calculations, for capacities and power, which are calculated and selected in accordance to numerous different factors.

Current and old tunnel ventilation system using jet fans installed in the ceiling

Fig.1

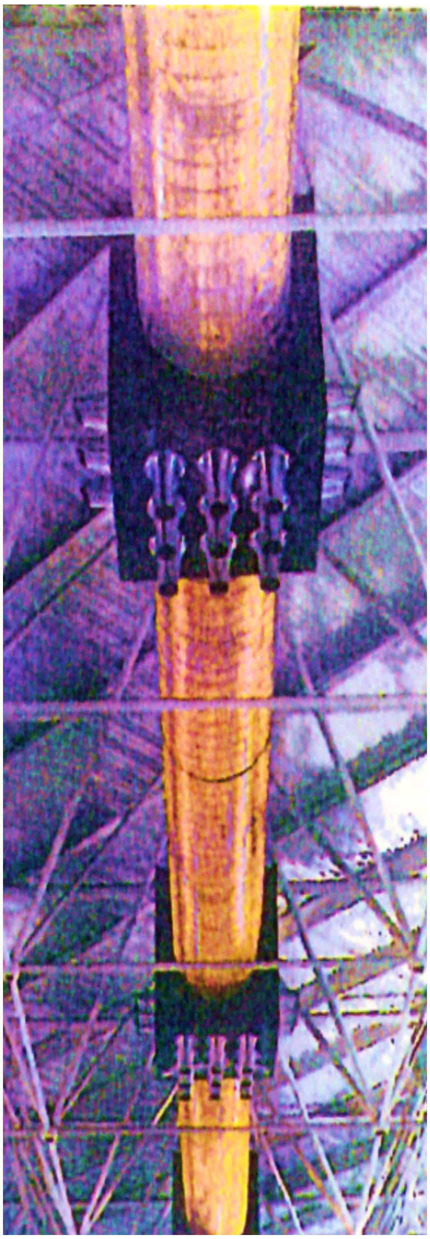
Suggested new system or method for tunnel air ventilation using air handling units, ducts, and supply diffusers.

Fig.2



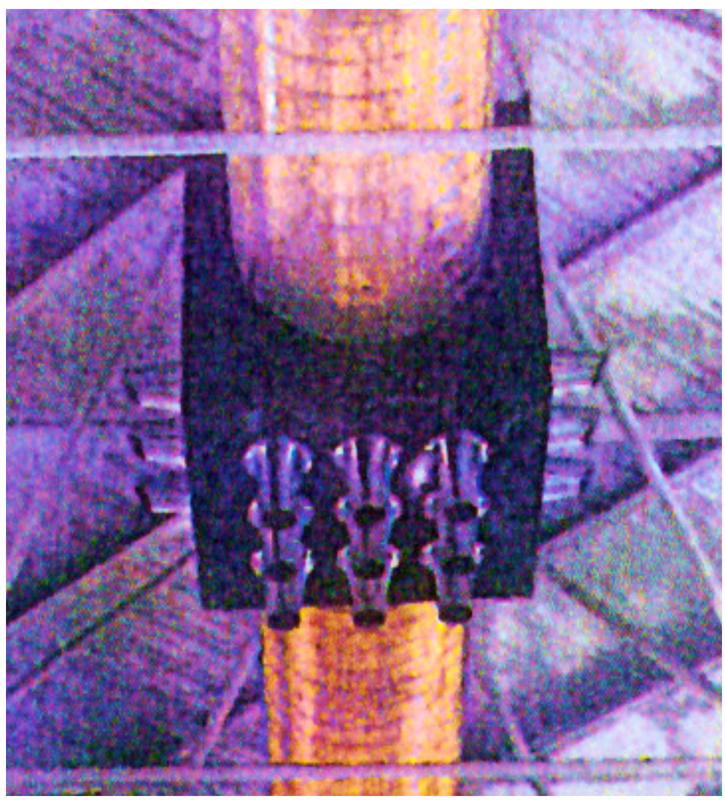
A preliminary longitudinal section for new method of tunnel ventilation. (sample)

Fig.3



The picture on the left shows the condition of the ducts and the diffusers, supplying fresh air throughout the tunnel.

There should be diffusers installed in the middle part of the tunnel versus on the sides based on the pollution density.



These procedures are normally done and repeated for most of the tunnels, and final result would be selection of a chain of jet-fans placed in the ceiling of the tunnel, in one or two longitudinal axis having certain distances from one another, which draws in the fresh air from one mouth of the tunnel, to the next mouth of it. This is a constant and continuous procedure. This chain of operation is done along the total length of the tunnel and moves the contaminants out of it.

Following are some brief descriptions of disadvantages, weak points, and operational difficulties of Jet-Fan Systems/ the conventional system in use today:

1- Financial needs of the system for heavy investment.

2- Substantial weight of the ceiling type jet fans, especially for double, triple or more fans, and the cost of special steel hangers.

Most importantly, since jet fans operate in chain formation, there are constantly and heavily working and depending on one another. Considering this fact, if one or two units in the chain are inoperable, it will create an operational gap within the system. Additionally, it has a negative effect on the safe and correct chain operation.

4- The Jet-Fan fan system needs a huge amount of cabling, and huge consumption of power, for both normal and backup supplies. The automatic system for the chain has also a complicated wiring network.

5- The system needs to maintain the electrical consumption for the units, which relates to the average consumption of each unit. The total consumption is substantial and the chain needs a high voltage transfer station for itself and its network. Therefore, the running cost of energy consumptions during the years of usage will accumulate to a very large number for the users.

6- Different tunnels are in need of different spare parts, that need substantial budget for different kinds and models, upkeep of units, storage, and operation.

7- Need for clear and precise warranties and specifications and manufacturer guarantees of part's operational integrity. More so, there is a need for higher level of technical skilled labors, which translates into higher wages and thus, bigger annual budgets.

8- A higher level of noise pollution within the tunnel and higher reflectance of sound during operation of the jet-fans (all encompassing).

9- There are limitations within the unit’s inspection, maintenance, set-up, and repair of different pieces that may cause temporary shutdown to the tunnel and traffic built-up, which is very costly to public and economy, or sometimes impractical to stop the traffic at all, making the repairs within tunnel impossible or very dangerous for the crew.

10- Since the ceiling fans are hanging from a cement and stone foundations, and they may become loose after a while, due to earth movements or vibration of the fans, there are hidden and probable danger factors from the weight and the vibration of the units (to fall on a vehicle, causing major damages/accidents or death to passengers).

The effect above can be even higher, if the frequency of rotation of all the fans matches the resonant frequency of a principal length or portion or component of the tunnel, which can be an unstable system, with vibrations, with growing amplitude, or with an increase of the amplitude very quickly. This will cause the whole system collapses, making it very dangerous for people and cars in the tunnel at that time.

11- There are considerable cost and change of designs, plus additional problems, if the design and construction of the chain fan system in some cases are incorrect, to re-do the whole system from scratch again.

12- Special consideration should be given to the pollutant in some countries mixed with the bits of desert sand. The Jet-Fan system has no filtration capabilities, causing the sand to fly like a bullet from the fan blade, with high speed, which can damage the cars seriously and can kill the people upon impact. In addition, designing filters for tunnel air ventilation system is not an easy task. The chain system will not purify the pollutant found in the air and acts as a vacuum.

However, the invention and embodiments described here, below, solve all these problems, and they have not been addressed or presented, in any prior art.

SUMMARY OF THE INVENTION

In one embodiment, we describe a method and system for Tunnel Air Ventilation, which is very practical, economical, and easy to install or implement. The repair and maintenance is safer and less expensive. The overall cost of installation and repair is lower. The system is more stable, and thus, safer for the vehicles and people. It is not damaged by sand, and it does not cause damage to vehicles by sand. So, the risk is minimized. The overall value for the government and society is very high.

The efficiency and low down time translates to a cleaner air in the tunnel, which is a major health issue for people, which causes sickness and even death for pollution and toxicity, or by fatal accidents in the tunnel, due to intoxication of the drivers or dizziness. The short term and long term effects on the health of drivers and passengers are huge, especially children, who are very sensitive to the polluted air or toxins, or for people with asthma or allergy, which can be fatal. Thus, our system and method can solve all these problems, with so many advantages, for millions of people around the world, and for many years to come.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The current and above mentioned flaws, cost, operational inefficiency, and archaic approach to the tunnel design have motivated the inventor here to come up with a new way to design an upcoming tunnel ventilation system.

As a result, we have a new way of approach to tunnel ventilation system that is more cost effective, with considerably fewer working parts, easier repairs, as opposed to difficulty in operation and changing parts, and heavy reliance on bad and old tunnel design.

Specification, differentiation, and the explanation of the new method:

The system or method is fundamentally based upon continuous "Partial Positive Pressure" (P.P.P.), which applies to the total volume of the tunnel. In the interest to clarify the suggested subject matter, we conducted a simple experiment that can prove the functionality of the new method.

The Experiment, to show the physics of our method and system:

We have done both experiment and simulation on this model: Using a horizontal pipe, which is partially sealed at both ends (4” in diameter and 6.5’ in length, or two meters), we insert dyed colored water and then use a syringe device. We introduce clean water through the middle of the pipe. The introduction of the clean water will force the dyed colored water to either side of the main pipe. The pipe, itself, acts as a representation of the tunnel and the clean water acts as the symbol of the fresh air that is purging the dyed colored liquid. The purging of the dyed colored liquid acts as the symbol of eliminatory factors of pollution. This experiment is the basic foundation of our method of tunnel ventilation. With removal of the pollution very efficiently in our experiment, we can conclude that the technique works for the real tunnels, as well, to improve the ventilation drastically.

•Ventilation Method:

Observing the experiment, it is seen that using one or two medium pressured centrifugal “Air Handling Unit Equipments”, each unit installed at either ends of the tunnel, and using one piece steel round section duct connecting the two equipments together, all along the length of the tunnel, make the ventilation operational for the tunnel. We will calculate and describe the specific number of diffusers amongst the length of the entire duct with certain “throwing angle of air” on certain points of the ducts, with the calculated volume of the outlet air, in an example below. Using the earlier experiment (pipe and dye water), described above, it is certain that the same basic rules and physics concepts can be applied to the real conditions for cleaning the polluted tunnel’s air. The features are described in more details below.

Strengths of Our Method:

1- One of the most important points of the method is that almost all needed parts for running the system can be made within most countries, and very economically.

2- Instead of installing heavy Jet-fans from the ceilings, which comes with some problems, as discussed before, the suggested method uses much lighter and more efficient materials, such as ducts and diffusers, which are simple to install without any danger involved. Additionally, there are no needs for special skills or extra cost involved for the installation.

3- The system is totally intertwined and moves the air perpetually through a chain of hundreds of diffusers, thus, the operation is non-stop and continues, unless there are shut down (or broken component) problems with the outside “Air Handling Units”, which is much less than problems happening for Jet-fans (current) systems.

4- In comparing the Jet-Fan system to our method, it is clear that the old system (Jet-Fan) is more labor intensive, uses large amounts of cabling, and much more wiring (for automatic controls). Looking from these angles, our system is much simpler and much less expensive.

5- It is simply clear that the power consumption of two or four medium pressure “air handling units” (i.e., 10-12’ pressure) is much less than the accumulated power consumption of 10s of jet-fans in the current systems.

6- Mentioning the simplicity of the method, it is apparent that upkeep and storage of spare parts (as well as price) in between the two systems favors our system drastically.

7- Using our method, there are additional advantages, like simplicity to change the diffusers and possibility to change the design and preventing issues with any kind of silencer on exit path of the “air handling units”. This is important because of the noise levels that are not in the same level between the two systems (i.e., Jet—Fan makes tremendous amounts of noise pollution, vs. our method, with minimal noise).

8- Our unit will need occasional maintenance, which are completely outside of the tunnel (i.e., air handling unit maintenance). No inside maintenance will be required, whatsoever, to interfere with traffic.

9- The system eliminates the need of heavy equipment within the tunnel, which cause danger and accidents.

10- The design and characteristics of the method is such that necessary design and maintenance modifications are very practical.

11- As opposed to the “jet-fan” system, which has no capability for air filtration, the new method has plenty of room for filtering and eliminating most kinds of air pollutants or particles.

12- The suggested method has some similarities to the transversal old method of ventilation, but, yet, it is completely different in design; details and costs.

So, our method is superior to the conventional methods in use in industry today. Comparison of Primary Energy Consumption between the Two Methods:

For example, the following is the approximate assessment between the two methods, for 2000 meters in length and about 45 square meters in cross sectional area.

A) Jet Fan Method:

In accordance to the standards of calculation per (PIARC, RUSSI, ASHRAE, or the like), the Jet-Fan system needs about minimum 30 pairs of duplex fans (or 60 single fans), in distances of approximately 70 meters apart. Each fan uses about 37 KW in power consumption, and therefore, about 2220 KWs of electricity consumption in total for all fans.

B) Our Method:

According to similar calculations, in case of using our method, we need the following items:

Four “Air Handling” units, type “Airfoil”. (Medium Total Pressure)

Each unit with capacity of 80,000-100,000 C.F.M. (cubic foot per minute).

10,000-12,000 SQ meters of spiral duct

About 150 boxes of air supply register.

About 1500 aerodynamic horns for air supply inside of the tunnel. (diffusers)

The individual power consumption of each air handling unit is about 75 KW, and 300 KW is the total consumption, which is much less than 2220 KW for the other method, mentioned above. So, our method is much more superior to prior art, in terms of power consumption and usage (or cost of usage or efficiency of operation).

The following is some examples or embodiments: At the 2 ends of the tunnel, we install 2 fans or sets of fans, with filters to get the sand, particles, toxins, or chemicals of fresh air, each set with multiple units or fans or multiple blades, e.g., 3-5 sets of blades or fans. Each one is equipped with an inverter and controller and processor for controlling the energy consumed/ used, based on the need and usage. It also has a unit for CO or CO2 gas detector or other particles, or with sensors with optical or spectrometer or other means, e.g. for toxins, for detecting and analysis, for gas or particles or chemicals. The result of analysis goes to the processor and controller to adjust the speed or opening angle or volume or cross section for fans or registers or openings, or to adjust angle of attack for fans, for position and tilt, with respect to horizontal axis or vertical plane. This will adjust the power and speed for the fans or number of fans operational or speed of fans with respect to each other, or the direction of the fans with respect to each other, or tilt of the fans with respect to each other, as relative value.

As an embodiment, each air supply system has 2 units, each with e.g. 50,000 ft^3/min, with a total of about 200,000 ft^3/min, maximum, in the worst case scenario, for bad quality of air.

The dynamic pressure on the fan is about e.g. 10-12 inches of water column pressure, for maximum level of operation. The maximum electrical consumption is about 75 KW for each unit, and thus, about 300 KW for all the system. Each unit has an inverter, and airfoil fan blades. Each motor has a variable speed, as well as bi-directional version, i.e., turning left and turning right in case of fire. Each unit has a bag (for filter for fresh air for each fan). Each unit has an anti-vibration and silencer to reduce noise or vibration.

As an embodiment, we will have about 2 CFM/ft^2 (cubic feet per minute, per 1 sqft of longitudinal cross sectional area of the tunnel). The average exchange rate of the air through whole tunnel space is about 5-10 air changes/h. At the maximum, for injection of air, the average speed for exit from each of the tunnel diffuser (horn) is about 175-250 FPM. We have a numerous series of sensors and analysis systems for CO and CO2 all along the tunnel space and length. A controller, getting feed from sensors and detectors (and a processor/ computer/server), decides the operation of the fans and the units, to optimize or command or decide, e.g., for speed, direction, tilt, which unit, and which combination of fans and units are operational, per each period of time.

This minimizes the pollution and particle concentrations in the tunnel, depending on traffic and concentration. So, it is flexible, dynamic, changeable, and optimized.

As an embodiment, we use the government mandate or recommendations, e.g., EPA, UN, PIARC, ASHRAE, ISAVT, local governments, and Federal rules and minimums or maximums, to control the air flow and filtering.

For example, for heavy traffic, with length of time in tunnel for each vehicle, in average, e.g., at 10-15 minutes, we set the maximum allowable concentration for health purposes as 50-75 PPM (parts per million) for all particles, as an example.

When fire happens inside tunnel, the units can reverse themselves, for exhaust or suction, against fire effects.

As mentioned before, the Jet fan systems in use today uses about e.g. 1000 or much more KW power, whereas our system uses 300 KW or more for the same tunnel, for injection method, which is more than 3 times improvement on efficiency and savings in cost. For a country with many tunnels, this can add up for millions of dollars, as the extra high power towers and reducing to low power stations (as the infrastructure for the tunnels, e.g., distribution system or boxes or units) are also very expensive to install and maintain.

In addition, much less cabling for power and control systems within tunnel are needed with our system, which adds to cost saving and differential or advantage for our system, for repair, installation and operation.

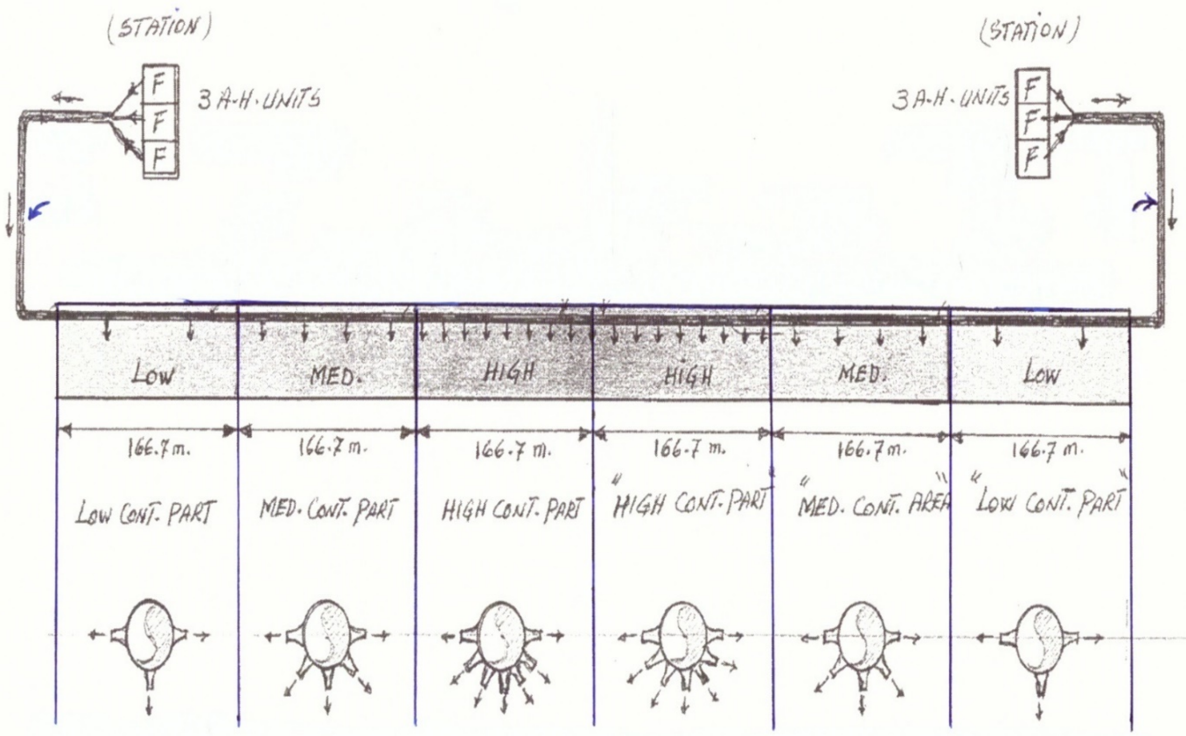
Also, probably, the shaking and vibration cause the fans on ceiling to get loose after a few years, without any or with low visible notice or warning, causing dangerous or fatal crashes or accidents in the tunnel, making our solution much safer, as it does not need such preventive inspections or repairs, which are very disruptive or dangerous for the traffic or repair crew. Note that our diffusers have no mechanical parts, with no heavy fans or motors attached to the ceilings.

ABSTRACT

In one example, we describe a method and system for Tunnel Air Ventilation, which is very practical, economical, and easy to install or implement. The repair and maintenance is safer and less expensive. The overall cost of installation and repair is lower. The system is more stable, and thus, safer for the vehicles and people. It is not damaged by sand, and it does not cause damage to vehicles by sand. So, the risk is minimized. The overall value for the government and society is very high.

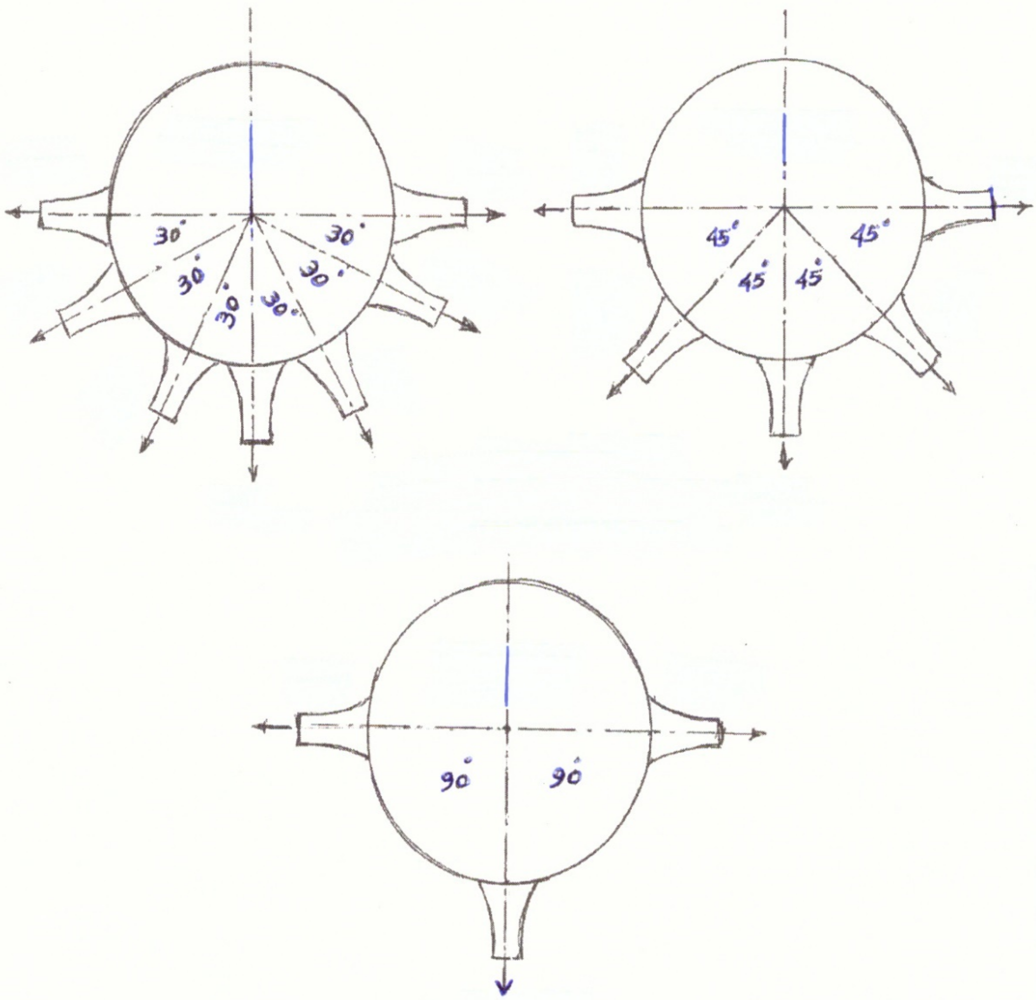
The efficiency and low down time translates to a cleaner air in the tunnel, which is a major health issue for people, which causes sickness and even death for pollution and toxicity, or by fatal accidents in the tunnel, due to intoxication of the drivers or dizziness. Different variations are also discussed and shown.

Fig.4



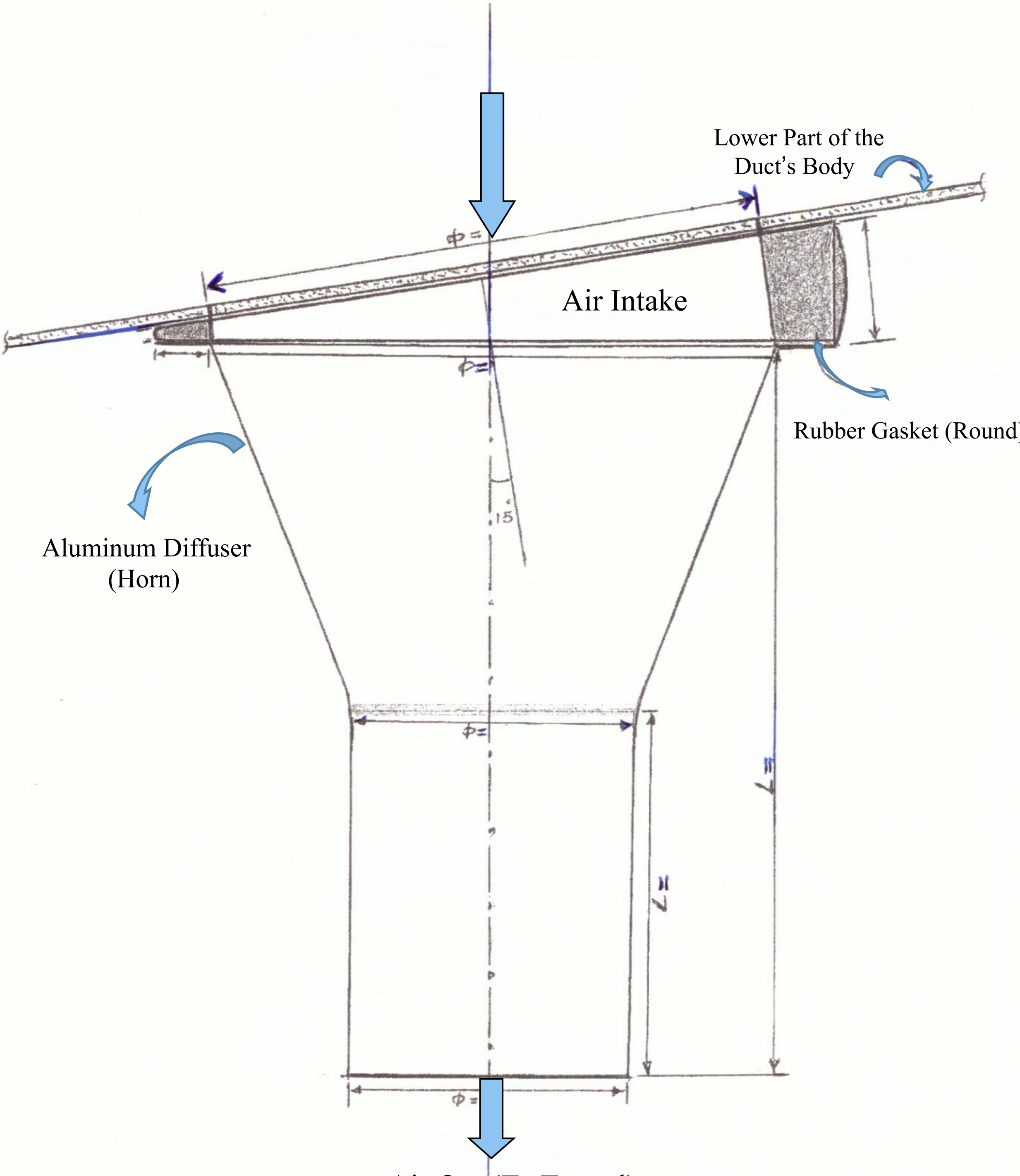
A preliminary longitudinal section which shows the base of new system of tunnel ventilation.

Fig.5

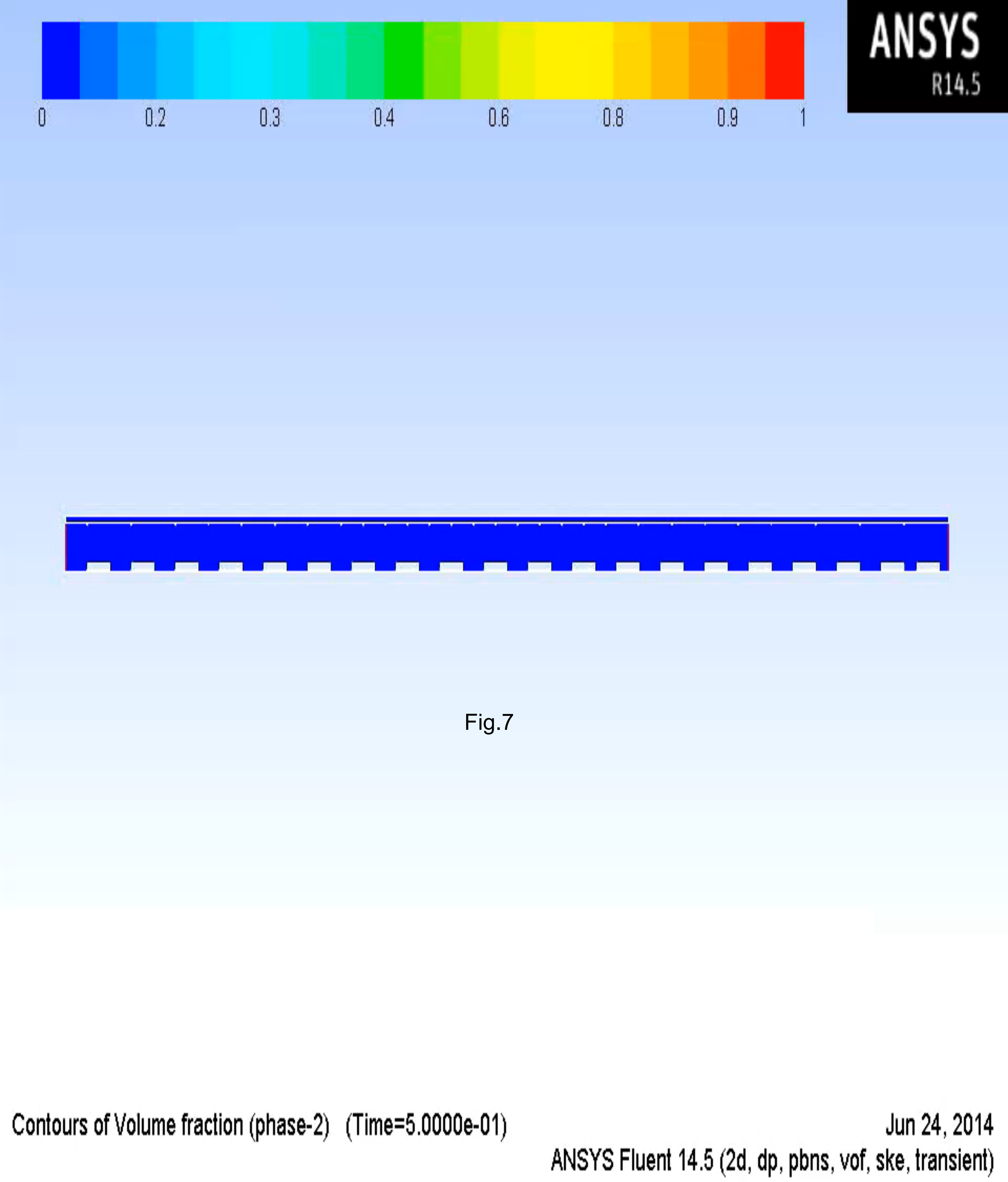


Rendering sections of 3 types of air inlet horns for high, med and low pollution areas of tunnel (inside).

Fig.6



Construction Detail of Horns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Contours of Volume fraction (phase-2) (Time=5.0000e-01)
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ANSYS Fluent 14.5 (2d, dp, pbns, vof, ske, transient)

Fig.7

Contours of pressure compound formation

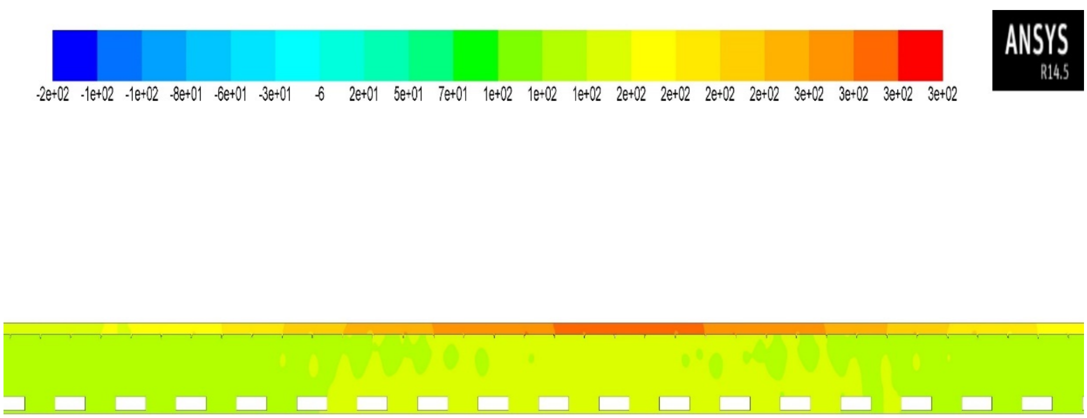


Fig.8

Contours of velocity one-way formation

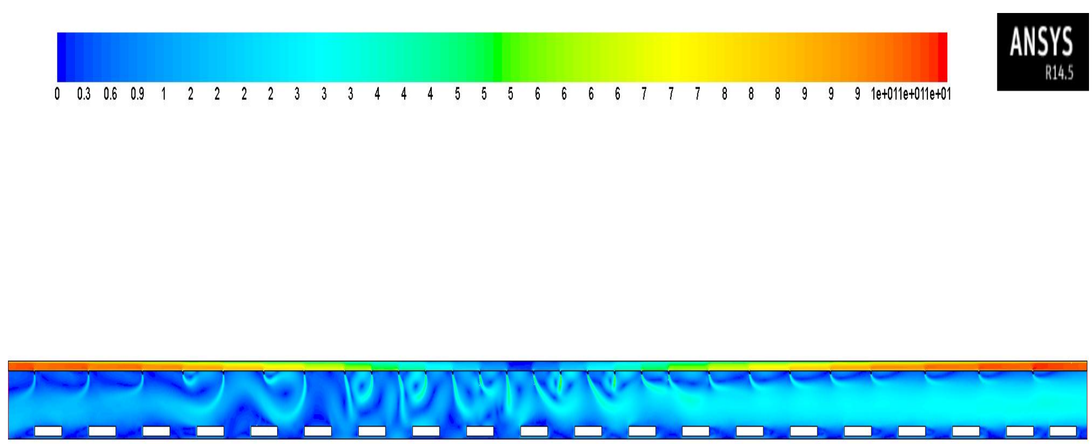


Fig.9

Contours of Velocity All Down Formation

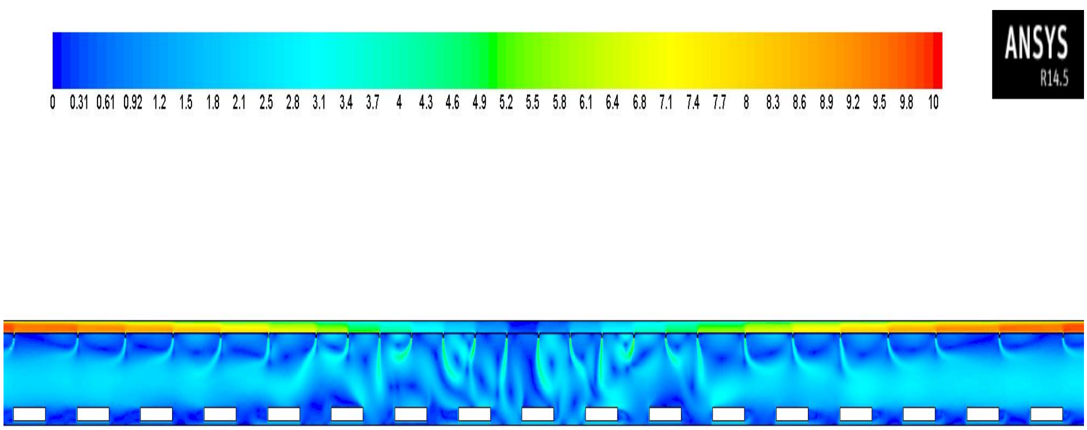


Fig.10

Contours of Velocity All Down Formation

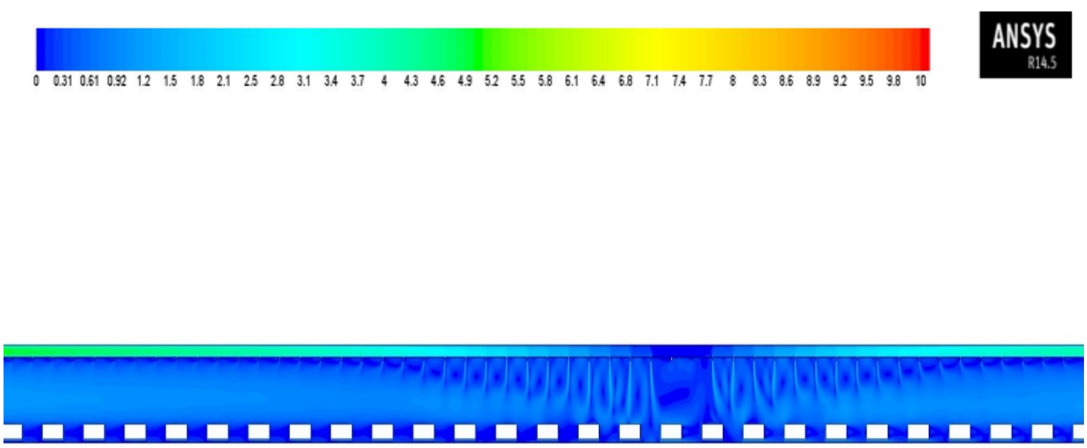
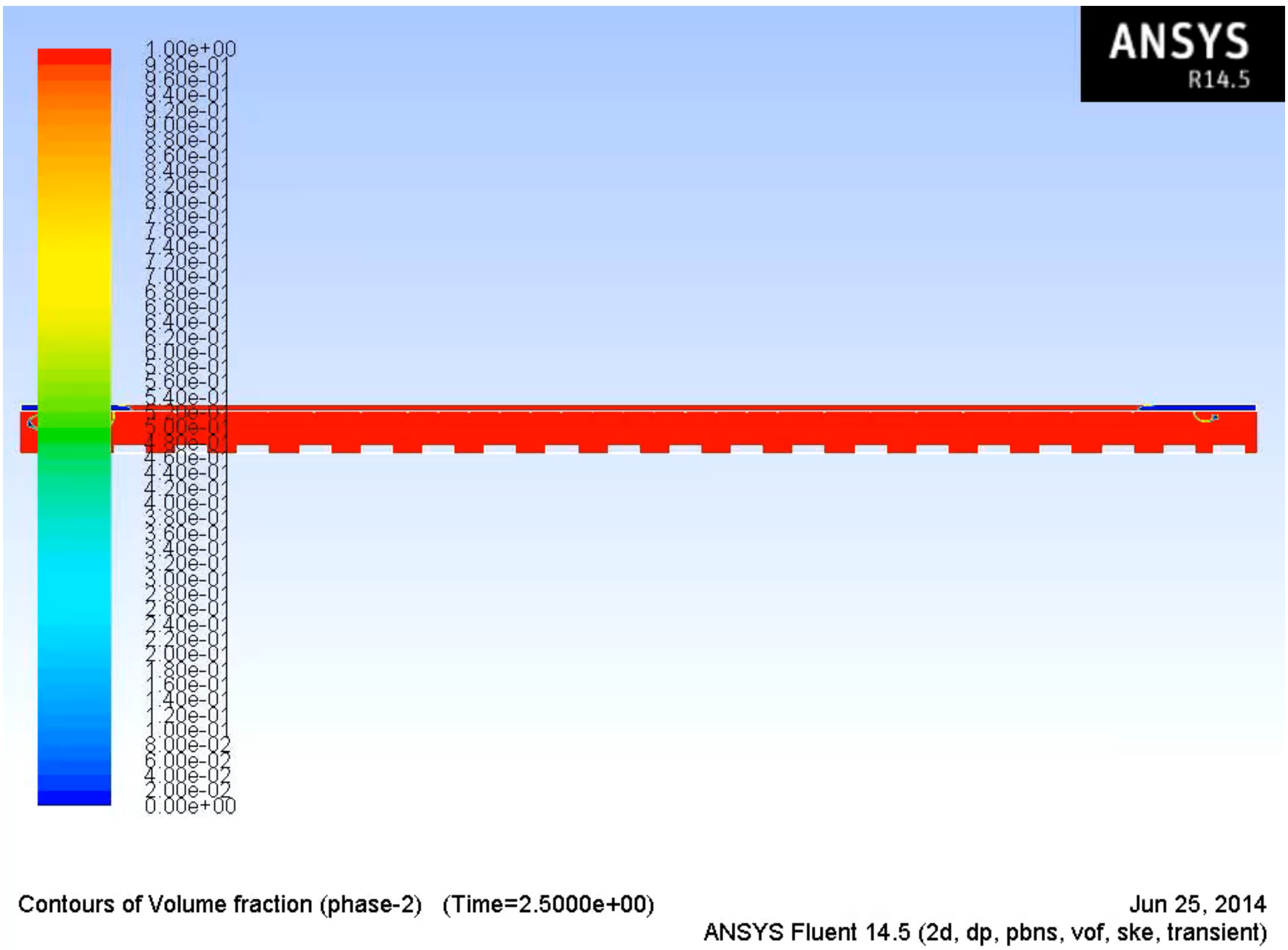


Fig.11

Fig.12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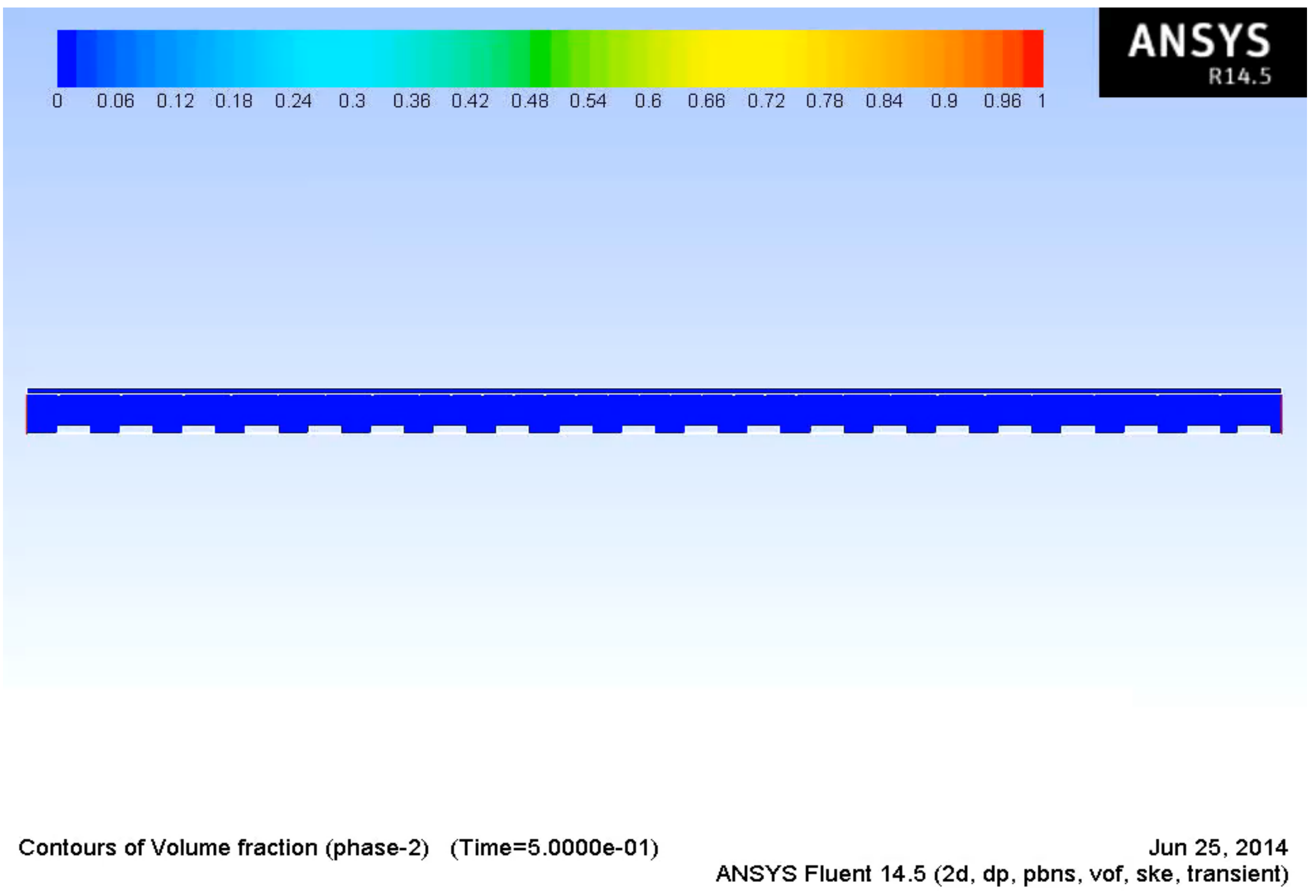
Jun 25, 2014
ANSYS Fluent 14.5 (2d, dp, pbns, vof, ske, transient)

Fig.13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Contours of Volume fraction (phase-2) (Time=5.0000e-01)
Jun 25, 2014
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