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OPTIMIZING VOLVO BUS AIR CONDITIONING SYSTEM DESIGN WITH HAP TECHNOLOGY

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Abstract: *Transportation is one the need of human being, which is existing since the evolution of mankind. Earlier it was fulfilled by using animals, later by bus. Hence requirement of comfort is utmost required during transportation. Today, the field if air conditioning design is more technologically challenging than ever before. While design innovations and product improvements promise sleeker, more versatile, more powerful and more energy – efficient air conditioners, the challenge today lies identifying the most appropriate product, or mix of products, for the application at hand. Indeed, today the emphasis is no more on understanding air conditioning 'products' but on creating 'solutions' and not just solutions, but 'customized solutions' that suit specific cooling need of specific business and establishments. The consultant or designer who understands the dynamics of those clients' business is more likely to offer better long term cooling solutions than who does not. Every air conditioning application has its own special 'needs' and provided its own challenges. Airports, hotels, shopping malls, office complexes and banks need uniform comfort cooling in every corner of their sprawling spaces and activities involving computers, electronics, aircraft products, precision manufacturing, communication networks and operation in hospitals, infect many areas of programming will come to a halt, so air conditioning is no longer a luxury but an essential part of modern living. In the present project the design of air conditioning is done for a Volvo bus, by considering the various parameters and by using Hourly Analysis Program to obtain efficient heat load calculation in order to get reliable and sustainable heat load. At the completion of the project the knowledge regarding designing the air conditioning of any automobile is gained.*

I- INTRODUCTION

Definition of air conditioning

In general air conditioning is defined as the simultaneous control of temperature, humidity, cleanliness and air motion. Depending upon the requirement, air conditioning is divided into the summer air

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conditioning and the winter air conditioning. The former uses a refrigeration system and a dehumidifier against a heat pump and a humidifier used in the latter.

Bus air conditioning

These systems cool the occupants of a vehicle in hot weather, and have come into wide use from the late twentieth century. Air conditioners use significant power; on the other hand the drag of a car with closed windows is less than if the windows are open to cool the occupants evaporative. There has been much debate on the effect of air conditioning on the fuel efficiency of a vehicle. Factors such as wind resistance, aerodynamics and engine power and weight have to be factored into finding the true variance between using the air conditioning system and not using it when estimating the actual fuel mileage. Other factors on the impact on the engine and an overall engine heat increase can have an impact on the cooling system of the vehicle.

Dehumidification

In an air conditioning system is provided by the evaporator. Since the evaporator operates at a temperature below dew point, moisture in the air condenses on the evaporator coil tubes. This moisture is collected at the bottom of the evaporator in a pan and removed by piping to a central drain or onto the ground outside. A dehumidifier is an air-conditioner-like device that controls the humidity of a room or building. It is often employed in basements which have a higher relative humidity because of their lower temperature (and propensity for damp floors and walls). In food retailing establishments, large open chiller cabinets are highly effective at dehumidifying the internal air. Conversely, a humidifier increases the humidity of a building.

Air-conditioned buildings often have sealed windows, because open windows would work against an HVAC system intended to maintain constant indoor air conditions. All modern air conditioning systems, down to small "window" package units, are equipped with internal air filters. These are generally of a lightweight gauzy material, and must be replaced as conditions warrant (some models may be washable). For example, a building in a high-dust environment, or a home with furry pets, will need to have the filters changed more often than buildings without these dirt loads. Failure to replace these filters as needed will contribute to a lower heat-exchange rate, resulting in wasted energy, shortened equipment life, and higher energy bills; low air flow can result in "iced-up" or "iced-over" evaporator coils, which can completely stop air flow.

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Additionally, very dirty or plugged filters can cause overheating during a heating cycle, and can result in damage to the system or even fire. It is important to keep in mind that because an air conditioner moves heat between the indoor coil and the outdoor coil, both must be kept just as clean. This means that, in addition to replacing the air filter at the evaporator coil, it is also necessary to regularly clean the condenser coil. Failure to keep the condenser clean will eventually result in harm to the compressor, because the condenser coil is responsible for discharging both the indoor heat (as picked up by the evaporator) and the heat generated by the electric motor driving the compressor.

Necessity of Air Conditioning

Air conditioning and refrigeration are provided through the removal of heat. Heat can be removed through radiation, convection, and by heat pump systems through a process called the refrigeration cycle.

The refrigeration cycle uses four essential elements to create a cooling effect. The system refrigerant starts its cycle in a gaseous state. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a "condensing coil" or condenser) where it loses energy (heat) to the outside. In the process the refrigerant condenses into a liquid.

II - PROJECT DESCRIPTION

The four major functions

To be effective, the automotive air conditioner must control four (4) conditions within the vehicle interior:

- It must cool the air
- It must circulate the air
- It must purify the air
- It must dehumidify the air

These functions are essential if passenger comfort is to be maintained when the ambient temperature and humidity are high. By performing these functions, the air conditioner maintains the body comfort of the passengers.

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Heat measurement

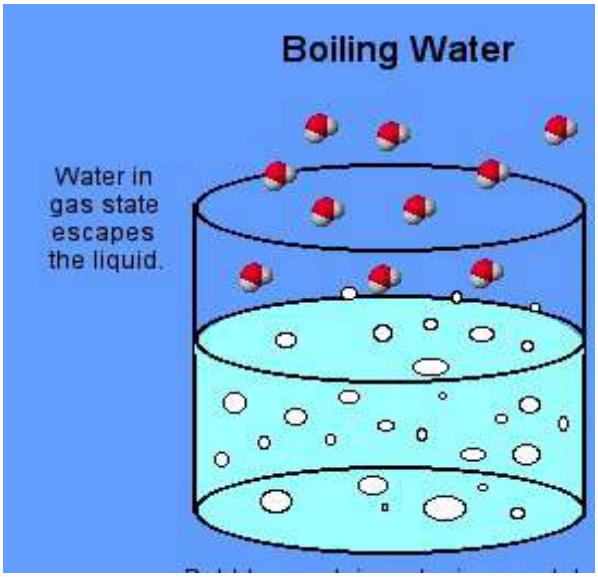

Fig 2.1 A: Boiling of water

A temperature reading gives us the heat intensity of a substance and not the actual quantity of heat. Heat quantity is measured in “KILOCLORIES" (KCAL's). One KCAL is the amount of heat required to raise the temperature of one kilogram of water one degree Celsius (at sea level). This quantity measurement is used in air conditioning to describe heat transfer during changes of state.

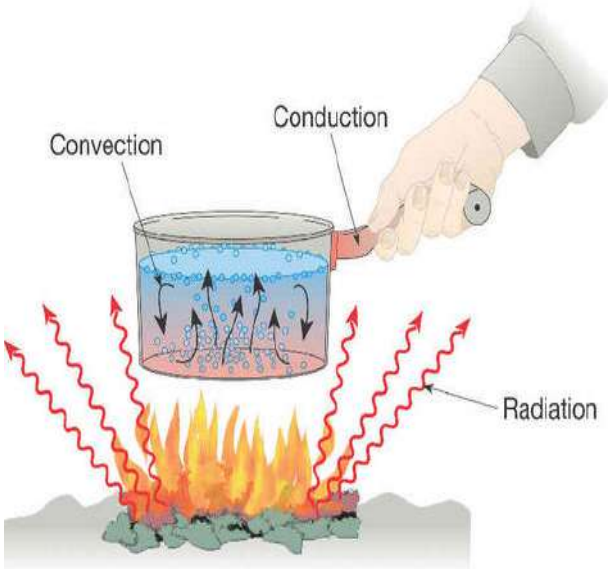

Fig 2.1 B: Direction of heat transfer

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2.3. Heat getting inside a vehicle

When a car is driven or parked in the sun, heat enters the vehicle from many sources.

All of these and other miscellaneous heat sources increase the air temperature within the vehicle. In a high ambient temperature situation, (e.g. on a 37°C Day), the interior of a vehicle left standing in the sun with windows closed could reach 65°C - 70°C.

The durability of vehicle systems is extremely important. Hours of operation are short compared to commercial systems, but the shock, vibration, corrosion, and other extreme conditions the vehicle receives or produces must not cause a malfunction or failure. Vehicle components are also exposed to many different types of chemicals such as road salt, oil, hydraulic fluid and engine coolant.

III - BUS SYSTEM TYPES

Heat Transfer

R134a in the LOW-PRESSURE side is COLD and can absorb large quantities of heat from the air moving over the evaporator. R134a in HIGH-PRESSURE side is HOT and the cooler ambient air moving over the condenser can absorb the heat from it.

Conduction

Conduction is the transfer of the heat through a solid object, liquid or gas. In order for the heat to be conducted, there should be physical contact between particles and some temperature difference. When one part of an object is heated, the molecules within it vibrate against one another, begin to move faster and more vigorously, when these molecules hit other molecules within the object, they cause heat to be transferred through the entire object.

Substances that conduct heat readily are called conductors, while substances that don't conduct heat readily are called insulators. Metal (e.g. copper, platinum, gold iron, etc) is a good conductor of thermal energy, aluminum is a good insulator. Wood falls somewhere in between. Conduction is greater in solids, where molecules are in constant contact.

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Convection

Convection is the transfer of heat energy between a solid surface and the nearby movement of a liquid or gas (such as air). As fluid motion goes more quickly the convective heat transfer increases. The presence of bulk motion of fluid enhances the heat transfer between the solid surface and the fluid. By this mode, heat is transferred when a heated air/gas or liquid moves from place to another, carrying its heat with it. The rate of heat flow will depend on the temperature of the moving gas or liquid and on its rate of flow.

Radiation

Heat energy is transmitted in the form of light, as infrared radiation or another form of electromagnetic waves. No medium is necessary for radiation to occur, for it is transferred through electromagnetic waves; radiation works even in and through a perfect vacuum (like) space) or air. Radiant heat transfer occurs between objects that are not touching. This is a direct transfer of heat from one object to another, without heating the air in between. The sun heating the earth is an example of radiant heat transfer. The sun warms the earth without warming the space between the sun and the earth.

An example of radiant heat transfer is found in a typical attic during the hot climate or summer. The sun radiates heat to the roof, which in turn radiates heat down toward the ceiling. If the insulation covering the ceiling does not effectively resist radiant heat transfer, then the ceiling will become increasingly warm - radiate heat down into the home - and the home will be uncomfortable. Properly applied insulation arrests radiant heat transfer.

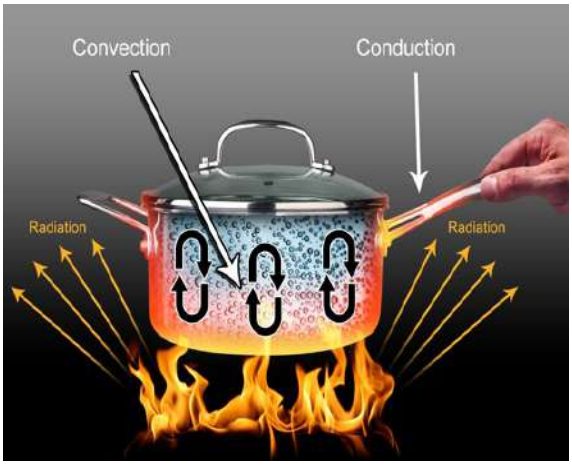

Fig No. 3.1 Modes of Heat Transfer

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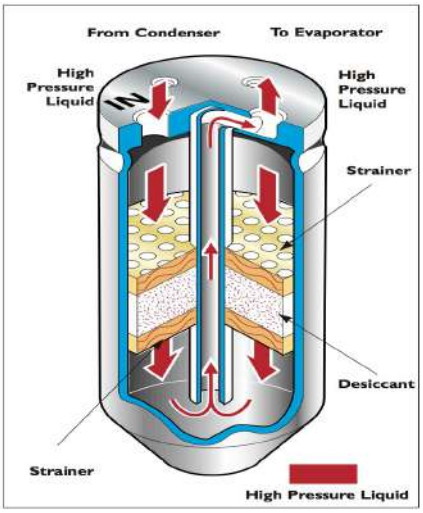
Steam

Water at boiling temperature diffused as a gas in the atmosphere. At standard temperature and pressure, pure steam (unmixed with air, but in equilibrium with liquid water) occupies about 1,600 times the volume of an equal mass of liquid water. For industrial applications, steam is usually used for heating, drying, humidifying, and for mechanical processes. Steam condensation heat transfer proves to be a much more effective and time-saving heating method than does convection heating with oil or other mediums.

IV - BUS COMPONENTS



Compressors

There are various makes and types of compressors used in automotive air conditioning systems operating on R134a.The internal design could be Piston, Scroll, Wobble plate, Variable stroke or Vane. Regardless, all operate as the pump in the A/C system to keep the R134a and lubricating oil circulating, and to increase the refrigerant pressure and thus temperature.

Compressor Clutch

The clutch is designed to connect the rotor pulley to the compressor input shaft when the field coil is energized. The clutch is used to transmit the power from the engine crankshaft to the compressor by means of a drive belt. When the clutch is not engaged the compressor shaft does not rotate and refrigerant does not circulate the rotor pulley free wheels. The field coil is actually an electromagnet, once energized it draws the pressure plate towards it, locking the rotor pulley and the pressure plate together causing the compressor internals to turn, creating pressure and circulating refrigerant.

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Condensers

The Condenser function is to act as a heat exchanger and allow heat to flow from the hot refrigerant to the cooler outside air.

R134a entering the condenser will be a high-pressure high temperature vapor. As the R134a vapor travels through the tubes of the condenser heat is given off to the cooler ambient air; the refrigerant vapor condenses and changes to a liquid state. The two types of condensers based on design are explained below.

Condenser electric fan

Most vehicles with air conditioning require an electric fan to assist air flow, either pushing or pulling the air through the condenser, depending on which side of the condenser the fan is placed.

The majority of vehicles using R134a require this additional Condenser cooling due to the higher operating pressures of R134a.

Also, most modern vehicles now have smaller grilles or bumper bar openings. This causes poor air flow conditions especially by the amount of air flow over the condenser.

The condenser fan is operated with A/C engaged in various ways:

- Medium pressure switch;
- Indirect connection to the compressor clutch
- Via the Electronic Control Module (ECM);
- Signal from the A/C switch activation.

Foam seals

These seals are fitted in between the condenser and radiator to prevent the heated ambient air exiting above, below or to the sides of the space in between (normally 25mm) the radiator and condenser.

If gaps are present between the condenser and radiator this heated air can be circulated back through the condenser. This results in the increased condenser temperature and causes reduction in the performances of the A/C system.

V - BUS AIR CONDITIONING DESIGN

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Cooling Load Factors

Occupancy

Occupancy per unit volume is high in automotive applications. The air conditioner must be matched to the intended vehicle occupancy.

Infiltration

Like buildings, bus is not completely sealed: wiring harnesses, fasteners, and many other items must penetrate the cabin. Infiltration varies with relative wind/vehicle velocity. Unlike buildings, bus is intended to create a relative wind speed, and engines may emit gases other than air. Body sealing and body relief vents are part of air-conditioning design for bus. Occasionally, sealing beyond that required for dust, noise, and draft control is required.

By design, vehicles are allowed to have controlled body leakage that allows air movement in the vehicle to provide comfort to the passengers, this also helps control moisture build-up and the occupants perceived comfort level. However, excessive body leakage results in loss of heating and cooling performance. Vehicle body leakage characteristics typically are significantly different in dynamic conditions in comparison to the static conditions. Air can leak from the vehicle's doors, windows, door handles, and trunk seals drafters allow a controlled exit for air from the cabin, and should be self-closing to prevent inflow when the body pressure is negative with respect to the exterior pressure. According to SAE standard J638, infiltration of untreated air into the passenger's compartment through all controlled and uncontrolled exit points should not exceed 0.165 m/s at a cabin pressure of 0.25kPa. However, each vehicle has different body leakage characteristics. Some vehicles have two drafters in-side the trunk on either side, and some have only one.

Insulation

Because of cost and mass considerations, insulation is seldom added to reduce thermal load; insulation for sound control is generally considered adequate. Additional dashboard and floor thermal insulation helps reduce cooling load. Some new vehicles have insulated HVAC ducts to reduce heat gain during cooling and heat loss during heating mode. Typical interior maximum temperatures are 93 degrees centigrade above mufflers and catalytic converters,50 degrees centigrade for other floor areas, 63 degrees centigrade for dash and toe board, and 43 degrees centigrade for side and top.

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Thermal Comfort and Indoor Air Quality

ASHARAE standard 55 provides information on the airflow velocities and humidity required to provide thermal comfort. Effective comfort cooling system design in cars must create air movement in the vehicle, to remove heat and occupants body effluents and to control moisture build-up. Assuring an effective temperature of 22 degrees centigrade with no solar load at 24 degrees centigrade, 98% of people are comfortable with zero air velocity of 2.5 m/s. If panel vent outlets can deliver sufficient air velocity to the occupants, comfort can be reached at a higher in-vehicle temperature than with low airflow.

VI - DESIGN USING HAP

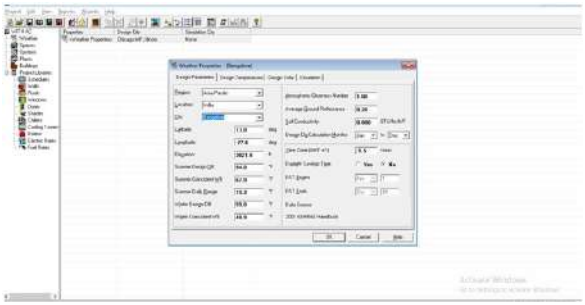

Fig: Selection of Weather properties

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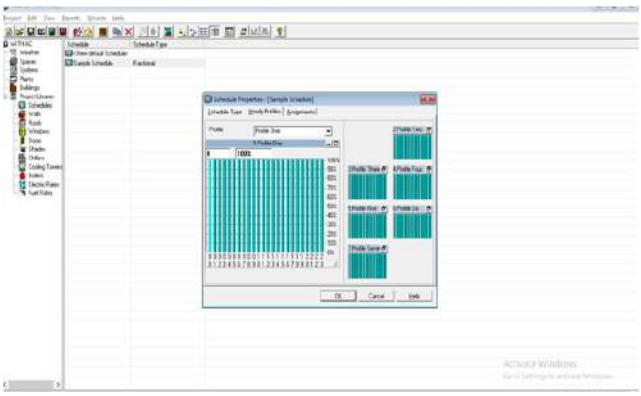

Fig: Selection of Schedule Properties

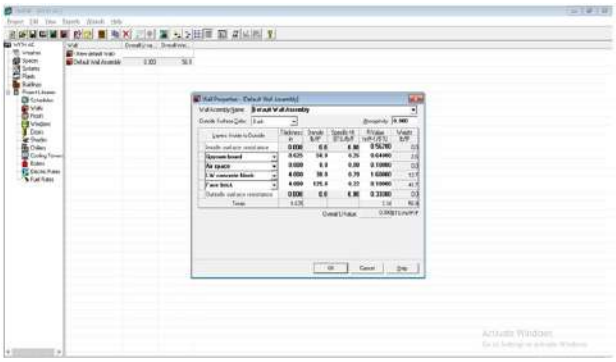

Fig: Selection of Wall Properties

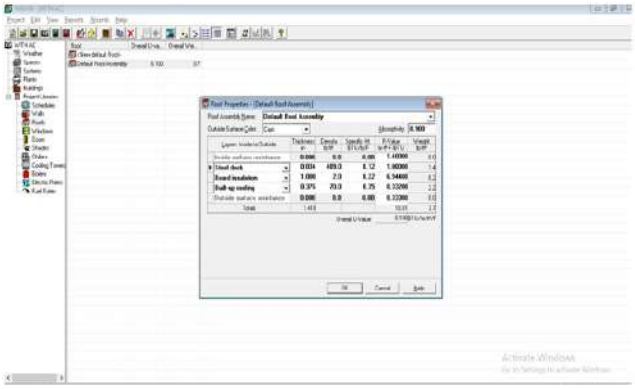

Fig: Selection of Roof Properties

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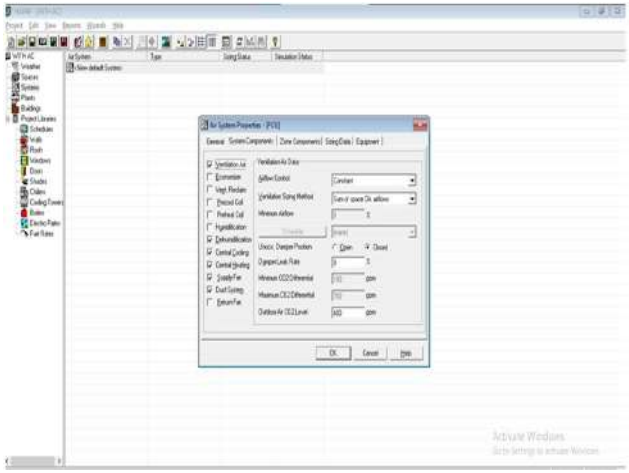

Fig: Selection of System Air Properties – Air flow Control

Air System Sizing Summary for 1F-CASS-01

Project Name: HAP for bus
Prepared by: B02 Students
Company: Individual

Air System Information

Air System Name	Air Handling Unit	Number of zones	1
Equipment Class	Bus type	Floor Area	300ft²
Air System Type	Constant Air Volume	Space	Bus
		Locaton	HYDERABAD, India

Sizing Calculation Information
Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	10.05 Tons	Load occurs at	Jun 1700
Total coil load	700MBH	OA DB / WB	105.6 / 77.9°F
Sensible coil load	12MBH	Entering DB / WB	82.9 / 70.4°F
Coil CFM at Jun 1700	880CFM	Leaving DB / WB	55.6 / 54.7°F
Max block CFM	880CFM	Coil ADP	52.6°F
Sum of peak zone CFM	880CFM	Bypass Factor	0.100
Sensible heat ratio	0.571	Resulting RH	67%
ft²/Ton	77.6	Design supply temp.	58.0°F
BTU/(hr-ft²)	154.7	Zone T-stat Check	1 of 1 OK
Water flow @ 10.0 °F rise	Nil gpm	Max zone temperature deviation	0.0°F

Central Heating Coil Sizing Data

Max coil load	88MBH	Load occurs at	Des Htg
Coil CFM at Des Htg	880CFM	BTU/(hr-ft²)	9.7
Max coil CFM	880CFM	Ent. DB / Lvg DB	66.8 / 69.8°F
Water flow @ 20.0 °F drop	2.62gpm		

Supply Fan Sizing Data

Actual max CFM	4000CFM	Fan motor BHP	4.71BHP
Standard CFM	4000CFM	Fan motor kW	3.74kW
Actual max CFM/ft²	3.20CFM/ft²	Fan static	1.00in wg

Outdoor Ventilation Air Data

Design airflow CFM	600CFM	CFM/person	15CFM/
CFM/ft²	0.71CFM/ft²		

VII - CONCLUSIONS & FUTURE SCOPE

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In this project Design of Air conditioning system in auto mobiles is done successfully for Volvo Bus. The parameters of the bus are 3200 cu.ft.

Finally, the output obtained is 8.25 TR. The Volvo bus considered is having Comfortable application. The aim of the Project is achieved by the designing.

THE FUTURE OF AUTMOBILE AIR CONDITIONING

Air conditioning system finds its use in various fields of our life. In case bus there has been a significant demand in the commercial trucks and buses including urban transport.

Urban Buses:

The Government of India has implemented city bus made by Volvo and Tata motors have in recent years installed with air conditioning system in various cities throughout India. This includes Volvo 8400 city bus.

Commercial trucks:

Commercial trucks producing companies such as AMW, Mahindra & Mahindra, Ashok Leyland and Tata Motors have introduced air-conditioned cabins in Tipper, haulage as well tractor trailer. Most of these cabins are found in the Tipper as these mostly work in mines and the working conditions are very uncomfortable.

Some of these are MN31 by Mahindra & Mahindra, TP2518 by AMW and such. The TIFFE-Project (Thermal Systems Integration for Fuel Economy) is devoted to the development of an innovative integrated vehicle thermal system to improve the on-board thermal management and the energy efficiency of the vehicle.

Some of the main contents are: Dual loop air conditioning, Development of innovative heat exchangers, Use of innovative coolants, The benefits can be summarized in a cost reduction (due to resize of the systems and their integration) and a remarkable fuel economy increase.

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