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Literature Review on Air Conditioning Heat load Analysis of a Cabin

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Abstract: ***Air conditioning system is necessary in automobile to maintain the comfort condition. Therefore, it is important to study transient response of vehicle under real driving conditions. The Heat Balance Method (HBM) is used for estimating the heating and cooling loads which develops inside the vehicle cabin. The Load Calculation of Automobile Air Conditioning System is calculated and presented. An hourly cooling load is calculated in Tirunelveli region with respect to its latitude. Tons of refrigeration required is also found out from the cooling load calculation and a review on cooling load calculation is also presented. This study gives overall cooling load and AC power consumption which can be used by HVAC engineers to design more efficient car AC systems. Only by knowing the cooling load and source of thermal load, we can develop intelligent system to reduce AC consumption.***

Environmental Control System (ECS) is a generic term used in aircraft industry for maintaining the required air temperature and pressure inside passenger and crew compartment. The real challenge for an ECS is to operate and supply adequate cooling over a wide range of ground and flight conditions in a most reliable and efficient manner. The most important aspect of ECS is to know the cabin heat loads during air cooling or air heating phases. A precise calculation of aircraft heat load would be a long process requiring detailed knowledge of the aircraft structure and of the quantities involved in the mechanism of heat pick up and interchange in the cabin. This paper describes a method that may be applied in calculating the heat load for any aircraft and calculations are shown for a typical light transport aircraft under the conditions that, the cabin altitude is maintained within 0 ft to 8000 ft (2438.4m) for the aircraft altitude of 0 ft to 25000ft (7620m). The system shall be capable of maintaining temperatures within 59°F to 75°F (15°C to 30°C).

Keywords: Heat Balance Method, Automobile, Air Conditioning, Environmental, Transport aircraft

I. INTRODUCTION

Air conditioning operation has direct impact on emission and fuel economy. The cooling system is important for the passenger comfort and thus it is important to study the transient response of room under real day light condition. The cooling load is a calculation that determines the amount energy (heat) that needs to be extracted from the cost with cooling. So after calculating the cooling load we can develop a system and structure with good efficiency to reduce the cost of cooling. Efficient design of mobile air conditioning (AC) has been the center of attention of automotive manufacturers and academic researchers during the last few decades. Reduction of fuel consumption and tailpipe emission are two crucial targets for the auto industry. This paper aims to provide a new and comprehensive model for estimating thermal loads in room cabins. AC operation had a substantial impact on emission and fuel consumption. Operation of room AC system over a range of environmental condition resulted in consisted increase in room emission of nitrogen oxides (NOx) and carbon monoxide (CO). NOx increase from 0.1 to 0.6 g/mile, depending on the ambient conditions. CO increased from 0.5 to 12g/mile. NOx emission increases due to the use of AC range from 15% to 100% of baseline values. The AC power consumption of mid-size cars is estimated to be higher than 12 -17% of the total room power during regular commuting.



Fig a) An array of air conditioner condenser units outside a commercial office building

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A. History

Air conditioning dates back to prehistory. Ancient Egyptian buildings used a wide variety of passive air-conditioning techniques. These became widespread from the Iberian Peninsula through North Africa, the Middle East, and Northern India. Passive techniques remained widespread until the 20th century, when they fell out of fashion, replaced by powered air conditioning. Using information from engineering studies of traditional buildings, passive techniques are being revived and modified for 21st-century architectural designs. An array of air conditioner condenser units outside a commercial office building. Air conditioners allow the building's indoor environment to remain relatively constant largely independent of changes in external weather conditions and internal heat loads. They also allow deep plan buildings to be created and have allowed people to live comfortably in hotter parts of the world.

B. Air Conditioning System

In order to more completely understand and quantify transient A/C system performance and its impact on vehicle fuel consumption and emissions, NREL has developed a transient A/C model using SINDA/FLUNT analysis software and is integrating it with the ADVISOR vehicle systems analysis software. The transient, one- dimensional, thermal-hydraulic model was developed using a nominal representative A/C system that was identified in discussions with NREL's automotive industry partners. This transient model captures all the relevant physics of transient A/C system performance, including two-phase flow effects in the evaporator and condenser, system mass effects, air side heat transfer on the condenser/evaporator, vehicle speed effects, temperature-dependent properties, and integration with a simplified cabin thermal model.

II. OBJECTIVES

1) To calculate the sensible and latent Heat gain from occupants.
2) TO CALCULATE THE HEAT LOAD OF CABIN AREA.

Aim

To calculate the total cabin load with respect to study of Human Comfort.

III. LITERATURE REVIEW

1) *"Cooling Load Calculation And Design Of Air Conditioning System In Automobile", B. Paul Vinofer, S.Rajakumar, International Journal of Research in Social Sciences And Humanities*

Abstract:- Air conditioning system is necessary in automobile to maintain the comfort condition. Therefore it is important to study transient response of vehicle under real driving conditions. The Heat Balance Method (HBM) is used for estimating the heating and cooling loads which develops inside the vehicle cabin. The Load Calculation of Automobile Air Conditioning System is calculated and presented. An hourly cooling load is calculated in Tirunelveli region with respect to its latitude. Tons of refrigeration required is also found out from the cooling load calculation and a review on cooling load calculation is also presented. This study gives overall cooling load and AC power consumption which can be used by HVAC engineers to design more efficient car AC systems. Only by knowing the cooling load and source of thermal load, we can develop intelligent system to reduce AC consumption.

2) *"Comprehensive Modeling of Vehicle Air Conditioning Loads Using Heat Balance Method", Mohammad Ali Fayazbakhsh and Majid Bahrami, Simon Fraser University*

Abstract:- The Heat Balance Method (HBM) is used for estimating the heating and cooling loads encountered in a vehicle cabin. A load estimation model is proposed as a comprehensive standalone model which uses the cabin geometry and material properties as the inputs. The model is implemented in a computer code applicable to arbitrary driving conditions. Using a lumped-body approach for the cabin, the present model is capable of estimating the thermal loads for the simulation period in real-time. Typical materials and a simplified geometry of a specific hybrid electric vehicle are considered for parametric studies. Two different driving and ambient conditions are simulated to find the contribution and importance of each of the thermal load categories.

3) *"Optimization of Vehicle Air Conditioning Systems Using Transient Air Conditioning Performance Analysis", Terry J. Hendricks, National Renewable Energy Laboratory*

Abstract:- The National Renewable Energy Laboratory (NREL) has developed a transient air conditioning (A/C) system model using SINDA/FLUINT analysis software. It captures all the relevant physics of transient A/C system performance, including two-phase flow effects in the evaporator and condenser, system mass effects, air side heat transfer on the condenser/evaporator, vehicle speed effects, temperature-dependent properties, and integration with a simplified cabin thermal model.

It has demonstrated robust and powerful system design optimization capabilities. Single-variable and multiple variable design optimizations have been performed and are presented. Various system performance parameters can be optimized, including system COP, cabin cooldown time, and system heat load capacity. This work presents this new transient A/C system analysis and optimization tool and shows some high-level system design conclusions reached to date. The work focuses.

4) *"Air Conditioning Heat Load Analysis of a Minibus Passenger Cabin Considering Radiation Effect", Nikhil Hajgude, Pankaj Ratnaparkhi, Vikramsinha V. Mane, International Research Journal of Engineering and Technology (IRJET)*

Abstract:- The design of minibus is to maintain the thermal comfort under the fluctuating driving conditions like the heavy summer condition and the highway and during the city traffic. The design of bus HVAC duct is to be designed for carrying conditioned air, divide the air so that it gives uniform air temperature distribution inside passenger compartment. In Indian market the minibus segment is very popular as well as in global market also. due to the unstable global climate change, which means longer hot summer and shorter winter season the HVAC requirement is increases in automotive segment.

The customers also need a promising HVAC unit, which not only maintains the thermal comfort efficiently under fluctuating ambient temperature but also helps to get the class-A comfort as per ASHRAE Standard. The thermal comfort of occupant in passenger compartment has become more important due to their increasing mobility leading to more time spent by people inside vehicle.

5) *"An Analytical Model Of Air-Conditioned Motor Vehicle Cabin", 7th International Congress Motor Vehicles & Motors 2018*

Abstract:- An air-conditioner used to control microclimate in a vehicle cabin works under specific conditions and microclimate in the vehicle cabin has many differences compared to buildings. In an air-conditioned cabin it is necessary to obtain good air quality and comfortable environment keeping the power consumption as low as possible in the same time. In this paper typical features of automotive air-conditioner are modelled and analyzed using conventional and empirical equations of thermodynamics.

Qualitative and quantitative analysis of motor vehicle cabin's air-conditioning system were carried out. A thermal model of a driver and occupants are included in the model. The results have good matching with empirical values, making this approach suitable for fast theoretical analysis of automotive air-conditioning system as well as for educational purpose.

An air-conditioner (AC) of motor vehicle cabin is the largest power consumer, excluding the vehicle propulsion system. The goal of the vehicle's air-conditioning system is to as soon as possible make thermal state inside the heated cabin comfortable and to maintain the comfortable conditions during the drive. Measures that can be taken in order to reduce the power consumption are increase of the refrigeration system efficiency, reduction of the cabin heat gain and efficient use of the air-conditioned air. Apart from experimental researches of AC performances, many numerical and analytical methods are applicable. The purpose of the researches is manly to investigate influences of design parameters and operation modes on performance of an air- conditioning system. The goal is to optimize energy consumption and to obtain thermal comfort and good air quality for passengers.

6) *"Cooling And Heating Load Calculations -Estimation Of Required Cooling/Heating Capacity", Version 1 ME, IIT Kharagpur*

Abstract:- As mentioned in an earlier chapter, heating and cooling load calculations are carried out to estimate the required capacity of heating and cooling systems, which can maintain the required conditions in the conditioned space. To estimate the required cooling or heating capacities, one has to have information regarding the design indoor and outdoor conditions, specifications of the building, specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used etc.) and any special requirements of the particular application. For comfort applications, the required indoor conditions are fixed by the criterion of thermal comfort, while for industrial or commercial applications the required indoor conditions are fixed by the particular processes being performed or the products being stored. As discussed in an earlier chapter, the design outdoor conditions are chosen based on design dry bulb and coincident wet bulb temperatures for peak summer or winter months for cooling and heating load calculations, respectively.

As the name implies, heating load calculations are carried out to estimate the heat loss from the building in winter so as to arrive at required heating capacities. Normally during winter months the peak heating load occurs before sunrise and the outdoor conditions do not vary significantly throughout the winter season. In addition, internal heat sources such as occupants or appliances are beneficial as they compensate some of the heat losses. As a result, normally, the heat load calculations are carried out assuming steady state conditions (no solar radiation and steady outdoor conditions) and neglecting internal heat sources. This is a simple but conservative approach that leads to slight overestimation of the heating capacity. For more accurate estimation of heating loads, one has to take into the thermal capacity of the walls and internal heat sources, which makes the problem more complicated.

For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated as it involves solving unsteady equations with unsteady boundary conditions and internal heat sources.

In combination with experimental data, fast and reliable simulation model was obtained. More detailed generic model of entire system is developed in work of Arici et al., using the principles of thermodynamics. The methodology was validated by comparing the simulation results with the experimental results. The model allows testing the effects of design, component, and structural changes on the thermal conditions of the passenger compartment presented an analytical model of air-conditioned tractor cab with proposal of partial air recirculation. It was concluded that the partial air recirculation contribute to reduction of power consumption for air-conditioning, maintaining the air quality within the required limits. Fayazbakhsh and Bahrami developed the heat balance method for estimating the heating and cooling loads encountered in a vehicle cabin.

7) *"Strategy Guideline: Accurate Heating and Cooling Load Calculations", Arlan Burdick, IBACOS, Inc., June 2011*

Abstract:- The heating and cooling load calculation is the first step of the iterative HVAC design procedure; a full HVAC design involves more than the just the load estimate calculation. Right-sizing the HVAC system, selecting HVAC equipment and designing the air distribution system to meet the accurate predicted heating and cooling loads, begins with an accurate understanding of the heating and cooling loads on a space. The Air Conditioning Contractors of America (ACCA)

Manual J Version 8 provides the detailed steps required to calculate the heating and cooling loads. The accurate heating and cooling loads are used to right-size the equipment with ACCA Manual S Residential Equipment Selection, then to design the air distribution system and ductwork with ACCA Manual T Air Distribution Basics for Residential and Small Commercial Buildings and ACCA Manual D Residential Duct System Procedure. In the author's experience several factors have led to a general industry resistance to initially perform an accurate load calculation, which is necessary for the design of a right-sized HVAC system. Historically, energy codes did not address stringent levels of energy efficiency, and rules of thumb were developed for HVAC sizing that worked based on the construction at that time. Building enclosures have become more energy efficient as energy codes have become more stringent since 2000; however, these rules of thumb have not changed. Full credit should be taken for improvements such as better windows, enhanced air tightness strategies, and additional insulation.

8) *"Air Conditioning Heat Load Analysis of a Minibus Passenger Cabin Considering Radiation Effect", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 08 Issue: 09 | Sep 2021*

Abstract – The design of minibus is to maintain the thermal comfort under the fluctuating driving conditions like the heavy summer condition and the highway and during the city traffic. The design of bus HVAC duct is to be designed for carrying conditioned air, divide the air so that it gives uniform air temperature distribution inside passenger compartment. In Indian market the minibus segment is very popular as well as in global market also. due to the unstable global climate change, which means longer hot summer and shorter winter season the HVAC requirement is increases in automotive segment. The customers also need a promising HVAC unit, which not only maintains the thermal comfort efficiently under fluctuating ambient temperature but also helps to get the class-A comfort as per ASHRAE Standard. The thermal comfort of occupant in passenger compartment has become more important due to their increasing mobility leading to more time spent by people inside vehicle.

The authors suggest that the proposed model can be used in early stages of passenger cabin design to reduce CFD modelling effort and time of Cool Down Simulation. This tactic is very effective in designing efficient HVAC for electric buses, since an HVAC directly consumes energy stored in battery results in low travelling range. A heating, ventilation, and air conditioning (HVAC) system in a vehicle is used to control the internal temperature of the vehicle cabin.

It includes three subsystems, namely, heating, cooling, and air conditioning, that work together to provide purified air to the vehicle cabin, ensuring thermal comfort for drivers and passengers. The first challenge to properly size a vehicle A/C system is to define the vehicle air conditioning heat load requirement. Within automotive industry, a model to accurately define vehicle heat load is still under development.

Total Heat load for minibus ranges from 9kw to 14kw depending upon various design factors such as glass area, glass inclination, seating capacity and engine capacity. The summation of all loads encountered by cabin is total heat load of vehicle This total heat load should be taken away by HVAC.

9) "Estimation and Analysis of Cooling Load for Indian Subcontinent by CLD/SCL/CLF method at part load conditions", July 2019, Journal of Physics Conference Series 1240(1):012031, DOI:10.1088/1742-6596/1240/1/012031

Abstract–A total equivalent temperature difference (TETD) and cooling load temperature difference (CLTD) methods are developed in the excel spread sheets using Visual Basic Programming for calculating the cooling load for a building. The spread sheets are developed to eradicate the human error and time consuming task of manual calculations. TETD and CLTD methods programmed in spread sheets are easiest and fastest way to estimate the cooling loads as compared to that of the commercially available software's. The TETD method estimates the peak value of the cooling load and CLTD is used to estimate the cooling load on an hourly basis. Cooling loads estimated using TETD method and CLTD method are validated against CARRIER software HAPv4.9. However, there is a marginal difference in the obtained cooling load values of the spread sheets and HAPv4.9. For selecting the air conditioning equipment for a building, the accurate cooling load calculations are required. For peak cooling load, the solar peak time at a given location is required. The present work deals with the analysis of Solar Peak Time for Indian Sub-Continent, by varying the solar time and geographical directions. The variation patterns as a result of heat gains due to occupants, equipment and lighting in the building are analysed on hourly basis using the CLTD method. Similarly, the variation patterns of cooling load due to variation in outdoor dry bulb temperature and relative humidity are obtained for different cities across India by considering the same room psychometric conditions, internal loads and maximum solar peak time. The TETD method always over predicts the estimated cooling load.

10) "Cooling Load Calculations ASHRAE CLTD/SCL/CLF Method", By Eng. Chandana Dalugoda,, CEng MIE(SL), FASHRAE, MCIBSE, GCGI (UK), MConsE (SL), Managing Partner, Chandana Dalugoda Consultants, Colombo, Sri Lanka

Abstract – Cooling load comprises of both Sensible & Latent loads. Actually, only sensible heat or the sensible load occurs in the room and Latent Load is not part of the room. Latent heat is part of change of state, so inside the room it appears only as moisture but no latent heat exist or transfer. When moisture from the return air is condensed back to water on the cooling coil, latent heat of condensation is absorbed & is called the latent heat load. When calculating the thermal loads for building, it is very important that the heating & cooling equipment system be capable of maintaining adequate comfort under all reasonable conditions. But sizing cooling system for hottest temperature ever recorded will result in an oversized air conditioner that will more expensive than necessary to buy and often less efficient to operate. Extensive record of climatic condones for various countries can be found in 1997 ASHAR Handbook-Fundamentals. 2009 & 2013 ASHRAE Handbook Fundamentals CD Rom has additional details for most of the cities which has WMO weather station number.

Load calculation spread sheet, use (area x U x CLTD) to determine the load in Watts. U-factor for each composite structure needs to calculate and all physical dimensions of the building fabric should be obtain from drawings or actual measurements. Factors such as SHGF, CLTD, SC & properties of material could be found in ASHRAE Handbooks. Load calculations precedes with building survey with clearly labelled sketches. All the construction details, power, water availability, water quality reports & air quality should be obtain.

IV. CONCLUSIONS

In this study, a method for estimating cabin heat load by taking into account actual sun radiation variance was created. Additionally to it can determine the individual contributions of various heat sources and body panels, calculate the total heat load, and assess the effects of changing their design specifications. All sheet metal and insulation domains are not needed in simulation, resulting in a mesh count reduction of more than 50% and a reduction in simulation time of more than 50%.

Calculated overall heat transfer coefficient values at respective surfaces can be immediately applied to CFD domain. Future research goals for this project include simplified CFD simulation.

The results show that the maximum radiation flux through glass facing south was 579.2 W/m2 at 12 PM, which is less than traditional presumption avoiding system oversizing.

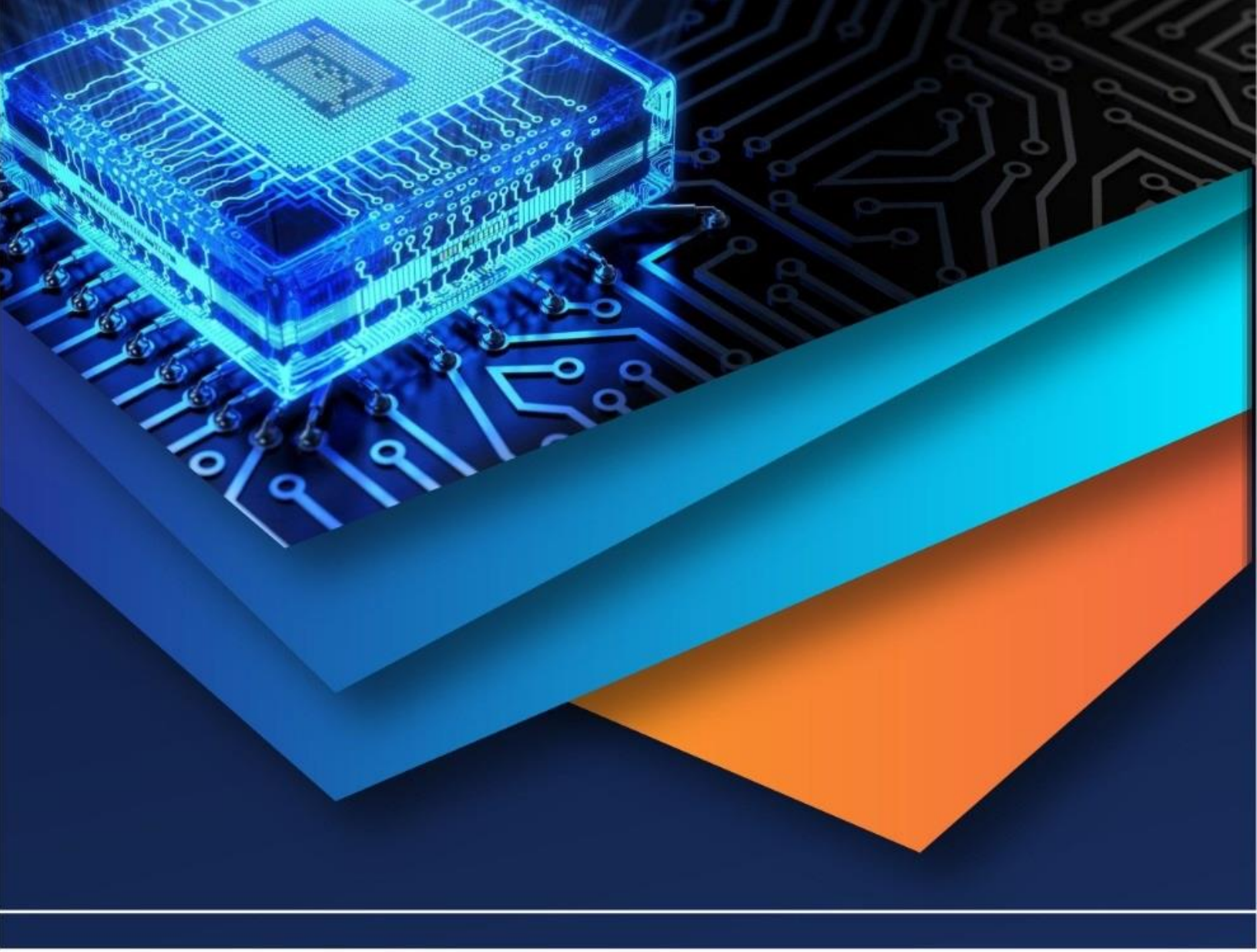
A 9434W cooling load is projected. 2.7 tonnes of refrigeration are required to design AC refrigeration. To reach the necessary thermal comfort levels, chosen heat exchangers must be able to remove 9434W of heat from the passenger cabin. This technology is highly useful for creating HVAC systems that are effective and give electric and hybrid automobiles longer driving ranges. The distribution of the cabin heat load can also be determined by computations. The primary load that affects cabin air temperature on average is solar radiation. Simple, quick, and precise calculations can be made by simply entering the vehicle geometry and the current weather. Any vehicle geometry can be used with the generated model.

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