iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VIII **Month of publication:** August 2020

DOI: https://doi.org/10.22214/ijraset.2020.31261

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

Design and Fabrication of Glycol Based Air Conditioning System

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Abstract: ***Now every day environment and weather change there are not constant through the year it's change day to day, hour to hour the temperature also change day to day place to place same as humidity which causes people Sick and lethargic. Which also causes illness, breathing and asthma problem in person and effect the working of person. But the Air conditioning use very heavy compressor used for refrigerant flow working which causes more electric consumption and more electric bill. In this project "DESIGN AND FABRICATION OF GLYCOL BASED ENERGY EFFICIENT AIR CONDITIONING SYSTEM", we replace the Air-conditioning System Compressor to a small domestic Refrigerator compressor (LG -1/8HP Compressor) and an additional Glycol based cycle is added on Vapour Compression Cycle, to reduce the compressor work. This change helps us overcome the electricity consumption rate as well as increase the Overall efficiency of cycle.***
Keywords: Air conditioning, Ethylene glycol, Liquid refrigerant, Modified System

I. INTRODUCTION

Now every day environment and weather change there are not constant through the year it's change day to day, hour to hour the temperature also change day to day place to place same as humidity present in nature also get changed. Which affect the humane health and its working .There for it's very essential for any work place to make it comfortable for working. We know that the physical property of air can be controlled by heating, cooling, humidification and dehumidification. This process is applied to maintain the desirable comfort level .There for simultaneously process of control of cleaning of air, humidity, temperature of air, air motion is known as air conditioning.

II. HISTORY

In 1902, the first Electrical air Conditioning unit was invented by Willis Carrier in Bufallo,New York.
In India the Voltas limited launched India's first air conditioning system 1954.Various development of Voltas in India are follow:

A. First split Air conditioning system in 1984
B. Floor standing Air Conditioning system in 1993
C. Sub One ton Air Conditioning system in 2000
D. First Star rated Air Conditioning system in 2007

III.BASIC PRINCIPAL OF AIR CONDITIONING

Air conditioners and refrigeration work in the same working principal. Air Conditioners Refrigerants that easily convert from gas to liquid and again liquid to gas. The Air Conditioning and Refrigeration System consist of four major parts:

A. Compressor
B. Condenser
C. Expansion Valve
D. Evaporator

In this system the working fluid or refrigerant arrives at the compressor as a cool low pressure .Gaseous form, the compressor compresses the refrigerant to a high temperature and pressure gas. After the compression done the refrigerant liquid leave the compressor and flow in to the Condenser. The condenser condenses the refrigerant hot gas to high pressure liquid. The high pressure condenses liquid Refrigerant goes in to the expansion device where the Refrigerant get expand and drop its pressure get drop. Now this liquid Refrigerant goes to the evaporator where the liquid change to gas and get evaporates its extract heat from air around it. By the time the working fluid leaves the evaporator and gets cooled down at low Pressure. This cycle run continuously in the system.

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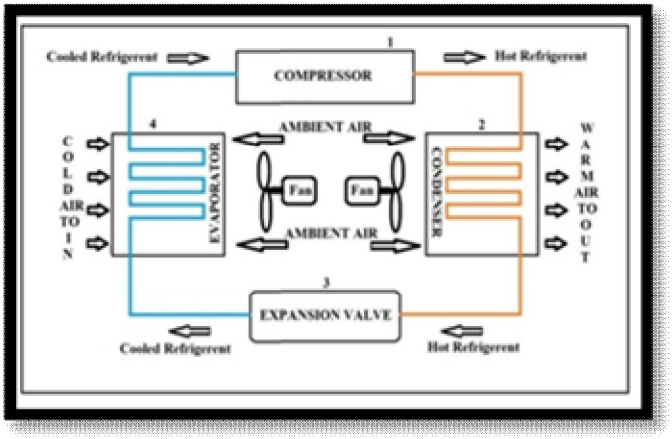

Fig. 1: Principal of Air Conditioning

IV. REFRIGERATION

If we talk about refrigeration it's nothing just a process of removing heat of the substance and leaves that heat in to environment. When we remove this heat to the environment the substance get cooled down. The process of removing or absorb the heat of a substance to make it cool is known as refrigeration effect. In a simple word the process of making the substance or product less than the environmental temperature by removing heat is call refrigeration and the fluid or substance which uses to absorb heat from substance is known as refrigerant.

A domestic Refrigeration system shown in fig. 2, which consist four part condenser, compressor, evaporator, cooling coil which act as a refrigeration system and fluid use is called refrigerant.

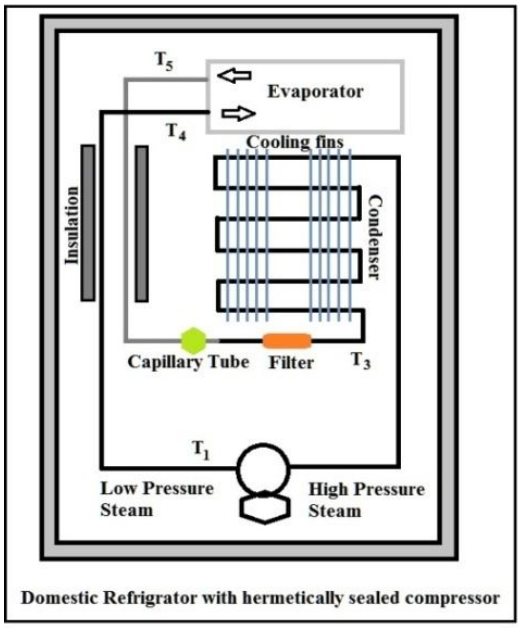

Fig. 2: Home Domestic Refrigeration Systems with Hermetic Sealed Compressor

V. REFRIGERATION USED IN THIS PROJECT

A. R-134a

R134a is also known as Tetrafluoro ethane (CF_3CH_2F) From the family of HFC refrigerant. With the discovery of the damaging effect of CFs and HCFCs refrigerants to the ozone layer , the HFC family of Refrigerant is widely used as there replacement. It's now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It's safe for normal handling as it is non-toxic, non-flammable and non-corrosive .Currently it is widely used in the air conditioning system in newer automotive vehicles.

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The manufacturing industry uses it in plastic foam blowing .Pharmaceuticals industry use it as a propellant. It exists in gas form when exposes to the environment as the boiling point temperature is -14.9° F or -26.1° C This refrigerant is not 100 % compatible with the lubricants and mineral based refrigerant currently used in R-12. Design Change to the condenser and evaporator to be done to use this refrigerant the use of smaller hoses and 30 % increases in control pressure regulation also have to be done to the System.

B. Physical Property of R-134a

Table 1: Physical Property of R-134a

S.No.	Physical property	Respective Measuring Unit
1	Boiling Point	-14.9 ° F or -26.1 ° C
2	Auto-Ignition Temp	1418 ° F or 770 ° C
3	Ozone Depletion Level	0
4	Solubility in Water	0.11% by weight 77 ° F or 25 ° C
5	Critical Temperature	252 ° F or 122 ° C
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

Unit of Measuring Refrigeration Capacity In British thermal unit (BTU) (1 Tons=28600BTU/24hr)
It's amount of heat required to melt 1 tone ICE.

VI. GLYCOL

Glycol any of class of organic compounds belonging to the alcohol family, in the molecular structure of glycol two hydroxyl (OH) groups are attached to different carbon atoms. The term is often applied to the simplest member of the class, Ethylene Glycol.

A. Ethylene Glycol

Ethylene glycol, also called 1-2 ethanediol, Molecular formula $HOCH_2CH_2OH$ is a colour less, oil liquid possessing a sweet test and mild colour. It is produced commercially form ethylene oxide, which is obtained from ethylene. Ethylene glycol is widely used as antifreeze explosive, and brake fluid. Ethylene glycol and some of its derivative toxic in nature.

B. Physical Property of Ethylene Glycol

Ethylene glycol is a cleared and transparent liquid has various properties like

1) Colour less liquid.
2) Solvable in Polarized liquid (Water and Alcohol)
3) Unsolvable or less solvable in Non-Polarized liquid. (Benzene and Toluene)

C. Other Physical Properties

Table 2: Physical property of Ethylene Glycol

S.No.	Physical property	Respective Measuring Unit
1	Boiling Point at 101.3 kPa	197.60 ° C
2	Frizzing point	-13.00 ° C
3	Density at 20 ° C	1.1135 g/cm ^{3}
4	Refractive index	1.4318
5	Heat of vaporization at 101.3Kpa	52.24 kJ/mol
6	Viscosity at 20 ° C	19.83mPa.s
7	Cubic expansion coefficient at 20 ° C	0.62x 10 $^{-3}$ K

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VII. MODIFICATION

Now every day environment and weather change there are not constant through the year it's change day to day, hour to hour. Temperature also change day to day place to place same as humidity which causes people Sick and lethargic. The Air Conditioning system help us to improve the work place environment suitable for human work and health by circulating filter air, remove dust partials and pollutant from air and control the humidity level and temperature of work place or room.

But the Air conditioning use very heavy compressor used for compression process of refrigerant. Flow which causes more electric consumption and more electric bill, in this project we replace. This compressor with a domestic refrigerator compressor and a glycol based secondary cycle to achieve the desired temperature in Air Conditioning System. The compressor work is reducing by external cooling by glycol cycle.

Fig. 3: AC Compressor and Domestic Refrigerator Compressor

VIII. WORKING OF MODIFIED SYSTEM

When we replace the Compressor of Air Conditioning system (Capacity 1.5Ton) with the small refrigerator compressor (Capacity 0.27Ton) the compressor lode increase due to low capacity of compression there for we add an external setup to overcome the compressor work. This external setup or arrangement is known as Secondary Cycle or Ethylene Glycol Based cycle in which we used ethylene glycol in a tank in the ratio of 50:50 for cooling process. In which cooling coil submerge in it with circulating pump which circulates ethylene glycol. We passed the Evaporator coil in the tank as show in dig. below. The refrigerant (R134a) exit from compressor to expansion valve entered in evaporator coil. Which is submerged in Ethylene glycol tank. Where the circulating Ethylene Glycol absorb the heat of refrigerant (R134a) before entering in compressor loss its heat and get cooled due to this Ethylene glycol there for this system pre condense the refrigerant (R134a) and when it's enter in to the compressor the compressor work reduced to du pre condensation of refrigerant (R134a).The cycle is running continuously same as shown in the diagram below.

Our Modification doesn't change the refrigeration cycle. It's only a secondary cycle which is used to reduce the refrigerant temperature to reduce the compressor works which increase the compressor efficiency.

Fig. 4: Modified System

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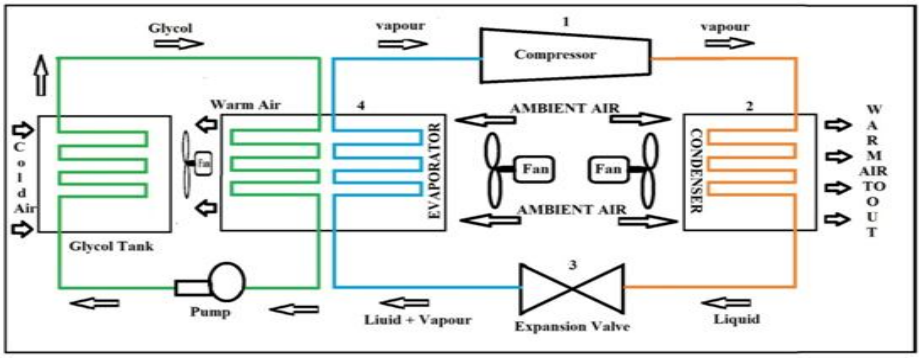

Fig. 5: Modified Air Conditioning System Cycle

IX. CALCULATION FOR MODIFIED SYSTEM

For the calculation of power consumption we made an experiment in which we use a 1.5 Ton Room AC (Electrolux) and set the AC at a temp of 30° C, 24° C, 18° C and note down the initial meter reading.

After this we note down the next reading after 3 hour duration and calculate the difference in reading and the unit consumption of the AC at temp of 30° C, 24° C, and 18° C. We repeat this process 2 to 3 times and different time interval and calculate the difference in meter reading end unit consumption of AC during this time period.

Table 3: Meter reading of Air Conditioning system

S.no.	Temp.	Initial Reading	Change After 3hr	Change After 6 hr	Change After 9 hr	Change After 24 hr
1.	30°C	3540.5	1.1	2.3	3.4	9.1
2.	24°C	3578.6	1.1	2.6	3.9	10.4
3.	18°C	3624.2	1.6	1.9	3.3	8.8
Average Reading			1.3	2.8	4.1	28.3

A. From above Reading

The meter reading of AC at 30°C after 24 hr = 9.1 Kwh
The meter reading of AC at 24°C after 24 h =10.4 Kwh
The meter reading of AC at 18°C after 24 h =8.8 Kwh
(Domestic meter rate decided by M.P. Gov. is 6.30 Rs/unit)
The total amount for running ac for 24 hours at 30°C = 9.1*6.30 = 53.33 Rs.
The total amount for running ac for 24 hours at 24°C =10.4*6.30 = 65.52 Rs.
The total amount for running ac for 24 hours at 18°C =8.8*6.30 = 55.44 Rs.

Now we repeat the same experiment with our modified system in which the AC compressor is replaced by domestic refrigerator compressor and ethylene glycol cycle. Time duration and temp of Air Conditioning system remain same 30°C at the duration of 60min, 90 min, and 120 min.(Reading is Included with Pump electric consumption to circulate the Ethylene Glycol)

Table 4: Meter reading of Modified Air Conditioning System

S.no.	Temp.	Initial Reading	Change After 3hr	Change After 6 hr	Change After 9 hr	Change After 4 hr
1.	30°C	31697.5	0.5	1.7	2.5	6.4
2.	24°C	31698.0	0.1	1.9	2.9	7.2
3.	18°C	31698.1	0.3	1.2	2.1	6.1
Average Reading			0.3	1.6	2.5	6.57

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B. From Above Reading

The meter reading of AC at 30°C after 24 hr = 6.4 Kwh
The meter reading of AC at 30°C after 24 hr = 7.2 Kwh
The meter reading of AC at 30°C after 24 hr = 6.1 Kwh
(Domestic meter rate decided by M.P. Gov. is 6.30 Rs/unit)
The total amount for running ac for 24 hours at 30°C = 6.4*6.30 = 40.32 Rs.
The total amount for running ac for 24 hours at 24°C = 7.2*6.30 = 45.36 Rs.
The total amount for running ac for 24 hours at 18°C = 6.1*6.30 = 38.43 Rs.

X. CALCULATION FOR COP

A. Observation Table

Table 5: Observation Table

T1	T2	T3	T4	Time
31.6	31.8	32	31.8	11:30AM
-17.8	32	31.2	31.3	12:50PM (AC Start)
10	18.4	22.1	22.4	12:55PM
15.4	24.4	28.1	26.4	1:00 PM
21.6	26.8	29.3	28.1	1:05PM
25	28	31	29.7	1:10PM

Where,

T1 = Ethylene Glycol Temp.
T2 = Cooling Coil Inlet Temp.
T3 = Cooling Coil Exit Temp.
T4 = Room Air Temp in °C.

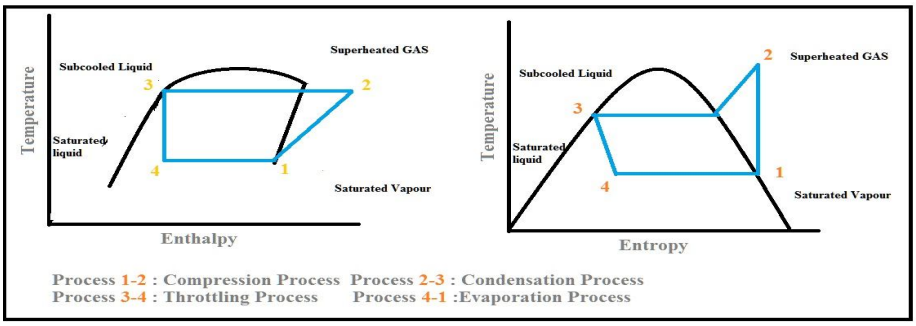

Fig. 6: T-h, T-s Diagram of System

From Modified VCR Cycle Physical Property of R134a in various condition of cycle:

Table 6: R134a Physical Property

Property of R134a	Stage -1-2	Stage -2-3	Stage -3-4	Stage -4-1
T (°C)	52.4	30	46.3	4.2
P (Kpa)	210	1203	1206	320
h (KJ /Kg)	276.2	278.3	117.8	252.90
s (KJ /KgK)	0.9106	0.9293	0.4245	0.54003
x	1 (For Vapour)	1 (For Vapour)	0 (For liquid)	0.44741
Condition of Refrigerant (R134a)	Super Heated	Super Heated Vapour	Saturated liquid	Liquid + Vapour

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B. Efficiency of the System

COP = Cooling Load / Work by Compressor + Pump Work to Circulate Ethylene glycol

Heat Rejection (cooling load in Evaporator) =

Q_R = (h1 – h4) * mass flow rate

{h4=h3 Isenthalpic Process}

Q_R = (276.2 - 117.8)*3 KJ /Kg

Q_R = 475.2 KJ /Kg

C. The work done by the Compressor

W = (h2 – h1) * mass flow rate

Mass Flow rate m^* = 3

W = (278.3 - 252.9) *3

W =76.2 KW

D. The work done by the Pump to Circulate Ethylene Glycol

W_p = weight of glycol Flow per unit time (1 min) * Pump Head in meter

W_p = 0.0620 kg * 2.4 mtr

W_p = 0.148Kg/min

W_p = 0.00002419 KW

COP = 475.2 / (76.2 + 0.00002419)

COP = 6.3

E. COP of domestic Air Conditioning System

COP = 3.5 * Capacity / Power consumed by compressor

COP = 3.5*1.5 ton / 1.7 KW/hr

COP = 3.08

We found that the Calculated COP of Modified System is Greater than the domestic air conditioning System.

XI. RESULT AND CONCLUSION

This Air Conditioning Unit take 70 min to bring the ethylene glycol temp 32 ^oC to -18 ^oC and after it get cooled continuously for the temperature difference 8 ^oC for first five minute and 5 ^oC for second five minute and reached at 1 ^oC after 20 minute.

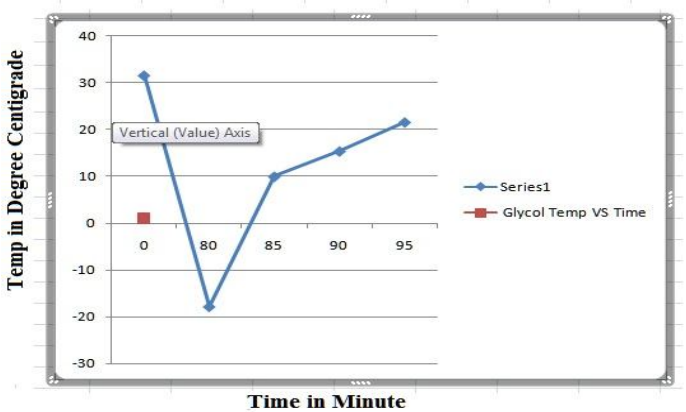

Fig. 7: Ethylene Glycol Temperature and Time

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As we can see that when Ethylene Glycol Get cooled the room temp get low with the time.

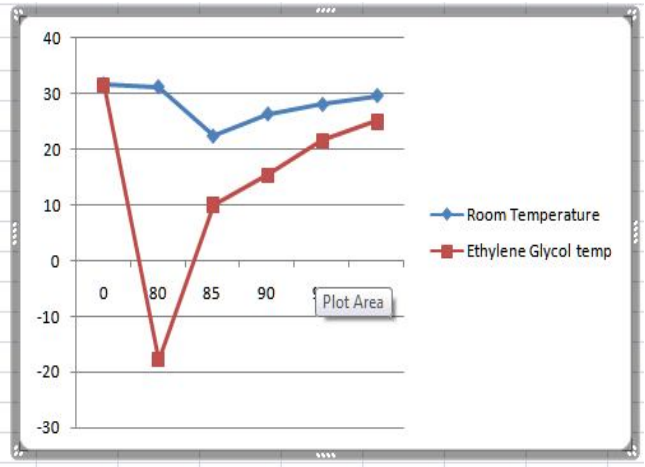

Fig. 8: Change in Ethylene Glycol and Room Temperature with Time

If we compare the domestic Air Conditioning system of (1.5 Ton) Capacity compressor and Our Modified Ethylene Glycol Based System with hermetically sealed compressor the electricity consumption rate is 30% lesser than the Domestic System. If we talk about the whole year electricity consumption rate of both systems the modified system is save 25 % to 30% electricity through the whole year. There for it's more efficient than the domestic Air Conditioning system with less noise pollution.

XII. COP OF MODIFIED SYSTEM

The COP of the modified Air Conditioning System is obtaining 6 which is very high compare to Domestic Air Conditioning System. Which make the system more effective and energy efficient.

XIII. LIMITATION OF SYSTEM

A. The modified system is more efficient compare to existing system but one drawback is we must on the system before 30 min. to cool the Ethylene glycol first.
B. After Some time the compressor get overheated.
C. Required large space compares to room Air Conditioning System.

XIV. FUTURE ENHANCEMENT

The modified system is more efficient compare to existing system and the energy consumption rate is also 30% less than the existing systems. The Drawback can be overcome by changing the compressor or changing the Cooling liquid or by changing the refrigerant. This can increase the system efficiency and working.

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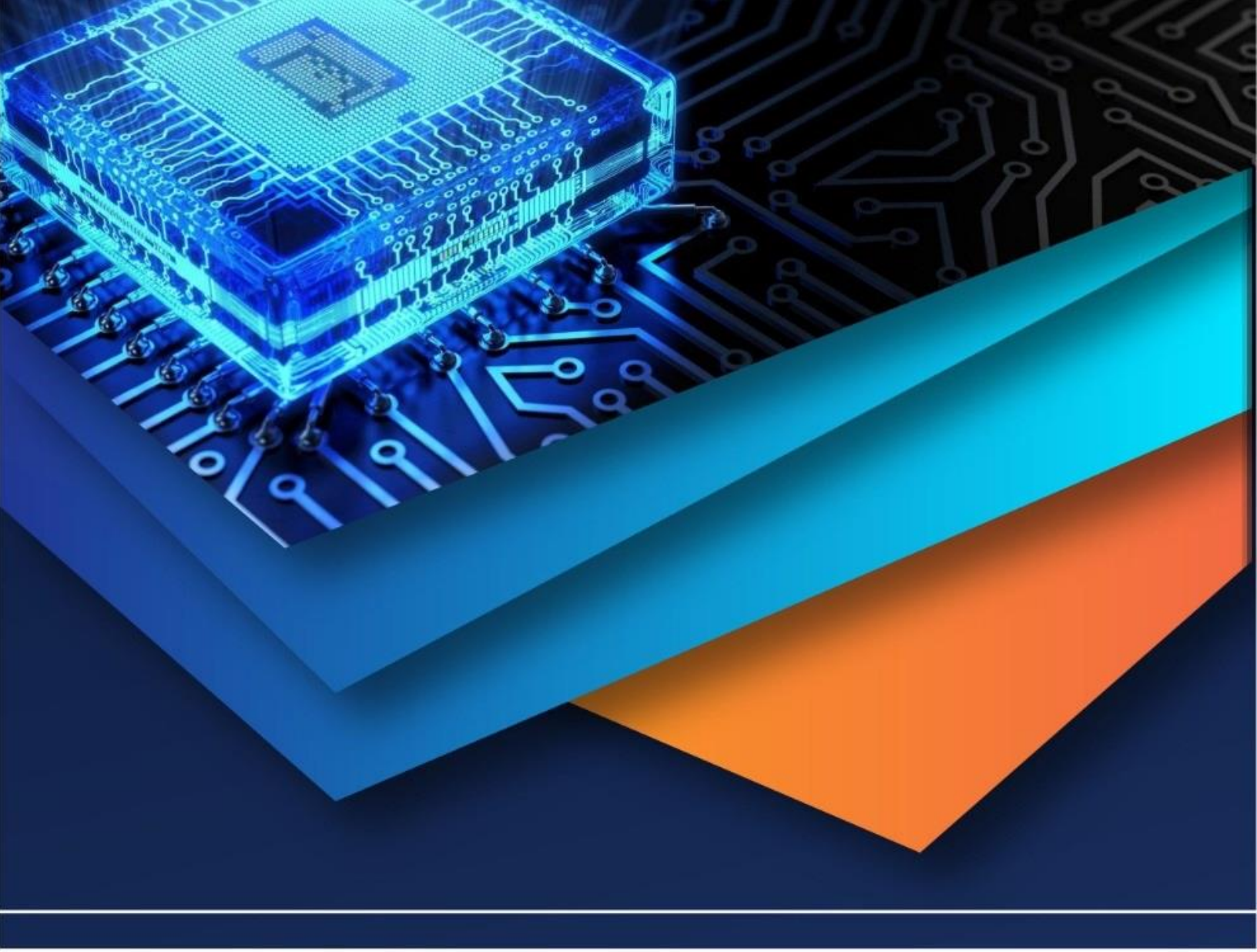

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