ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Finite Element Analysis to Determine Performance of Two Stage Vapour Compression Refrigeration System

Eswara Rao.T
Ellenki Institute of Engineering & Technology, Patelguda, Hyderabad, Telangana, India.

Mrs.V.Saritha
Ellenki Institute of Engineering & Technology, Patelguda, Hyderabad, Telangana, India.

ABSTRACT:
Refrigeration technology is based on the principle of rejection of heat to the surroundings at higher temperature and absorption of heat at low temperature. The main components of a vapor compression refrigeration system are the compressor, condenser, expansion valve and evaporator. Vapour compression refrigeration systems consume large amount of electricity. Coefficient of performance and exergetic efficiency are main two parameters to calculate the performance of refrigeration systems in the view to optimize the energy consumption. In this thesis, comparative analysis of R134a, R152a, R600 and R600a as refrigerants in two stage vapour compression refrigeration system is performed using finite element analysis to determine the heat transfer rates, pressure loss, and mass flow rates and compared for the refrigerants COPs. 3D modeling of the two stage vapour compression refrigeration system components is done in CREO. CFD and Thermal Analysis are performed in ANSYS.

I. INTRODUCTION:
Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important submissions of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used widely for providing thermal comfort to human lives by means of air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odor and flow, as required by occupants, a process, or products in the space.

The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The past of refrigeration is very exciting since every aspect of it, the availability of refrigerants, the prime movers and the advances in compressors and the methods of refrigeration all are a part of it.

Vapor Compression Refrigeration Systems:
The basis of new refrigeration is the ability of liquids to absorb enormous quantities of heat as they boil and evaporate. Professor William Cullen of the University of Edinburgh demonstrated this in 1755 by placing some water in thermal contact with ether under a receiver of a vacuum pump. The vaporization rate of ether increased due to the vacuum pump and water could be frozen. This process involves two thermodynamic concepts, the vapor pressure and the latent heat. A liquid is in thermal equilibrium with its own vapor at a pressure called the capacity pressure, which depends on the temperature alone.

If the pressure is increased for example in a pressure cooker, the water boils at higher temperature. The second concept is that the evaporation of liquid requires latent heat during evaporation. If latent heat is extracted from the liquid, the liquid gets cooled. The temperature of ether will remain constant as long as the vacuum pump maintains a pressure equal to saturation pressure at the desired temperature. This requires the removal of all the vapors formed due to vaporization. If a lower temperature is desired, then a lower saturation pressure will have to be continued by the vacuum pump. The component of the modern day refrigeration classification where cooling is produced by this method is called evaporator.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

If this process of cooling is to be made continuous the vapors have to be recycled by condensation to the liquid state. The condensation process requires heat rejection to the surrounds. It can be condensed at atmospheric temperature by increasing its pressure. The process of condensation was educated in the second half of eighteenth century. U.F. Clouet and G. Monge liquefied SO_2 in 1780 while van Marum and Van Troostwijk liquefied NH3 in 1787. Hence, a compressor is required to maintain a high pressure so that the evaporating vapors can condense at a temperature greater than that of the surroundings.

REFRIGERATION SYSTEM COMPONENTS

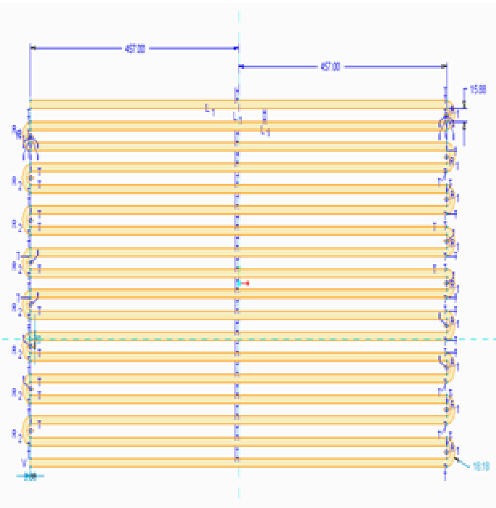
There are five basic components of a refrigeration system, these are:

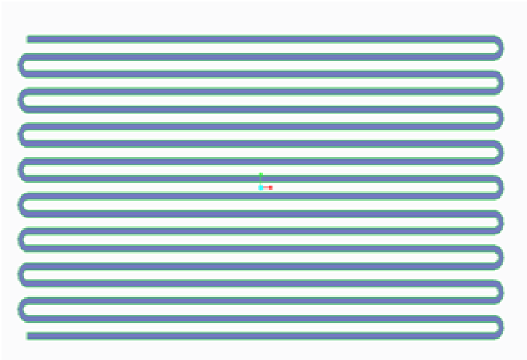
- Evaporator
- Compressor
- Condenser
- Expansion Valve
- Refrigerant;

Note:

DIMENSIONS ARE TAKEN FROM THE STANDARD INDUSTRIAL EQUIPMENT AND ALSO FLOW RATES ARE TAKEN IN THIS PROJECTS

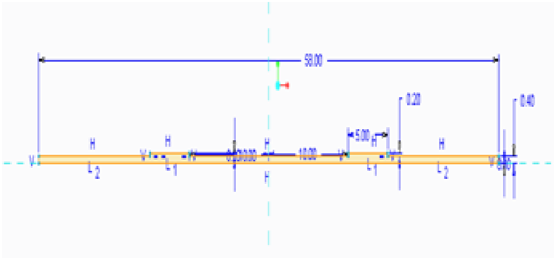
Evaporator

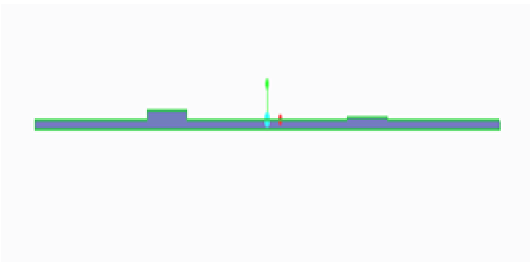




High pressure compressor 150cc

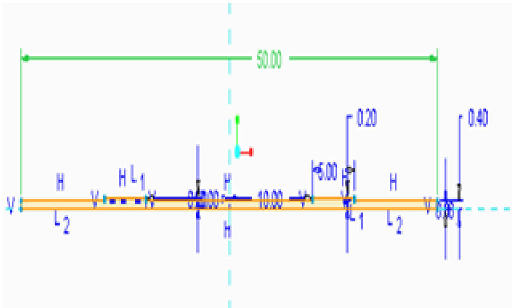
Bore diameter = 58 mm





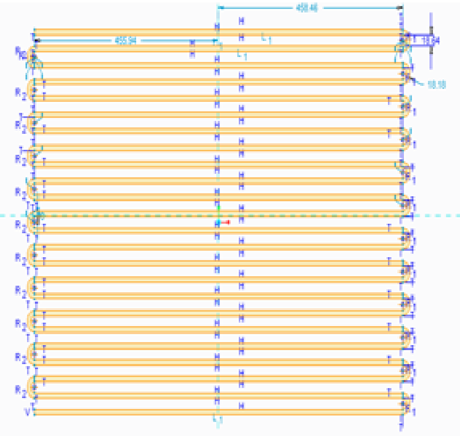
Low compressor = 110cc

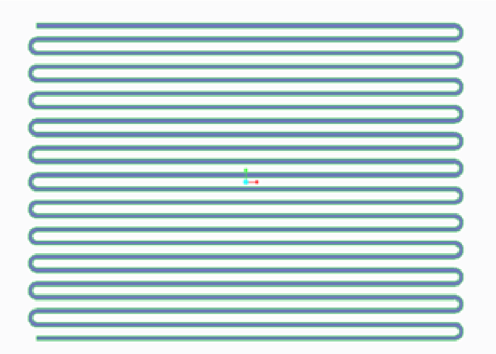
Bore diameter = 50mm



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

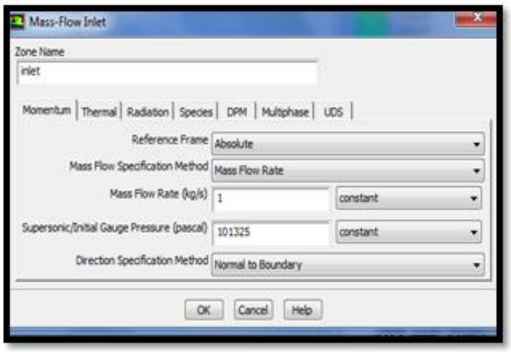
Condenser



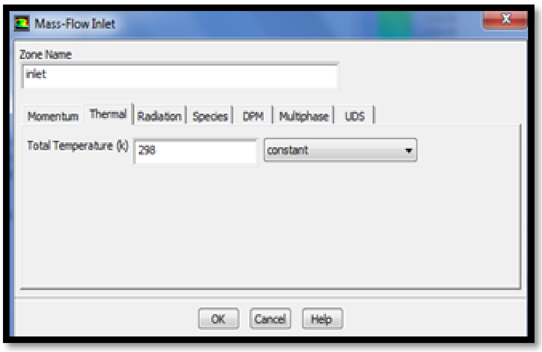


CFD ANALYSIS FOR EVAPORATOR R134A

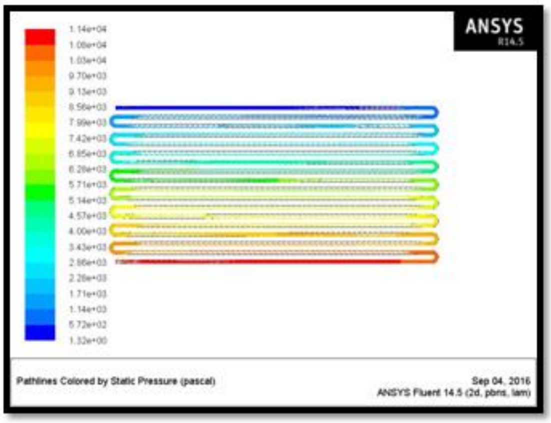
BOUNDARY CONDITIONS INLET



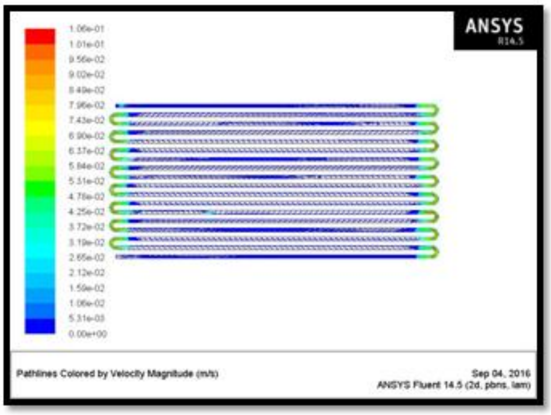
INLET TEMPERATURE



PRESSURE CONTOURS

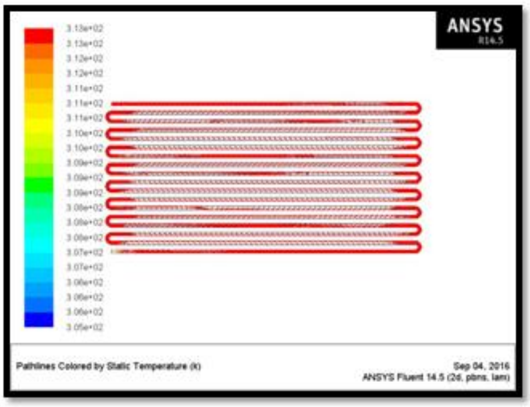


VELOCITY MAGNITUDE

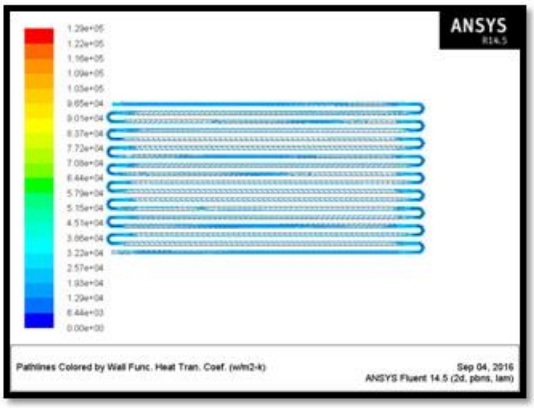


ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TEMPERATURE



HEAT TRANSFER COEFFICIENT



Total Heat Transfer Rate (w)

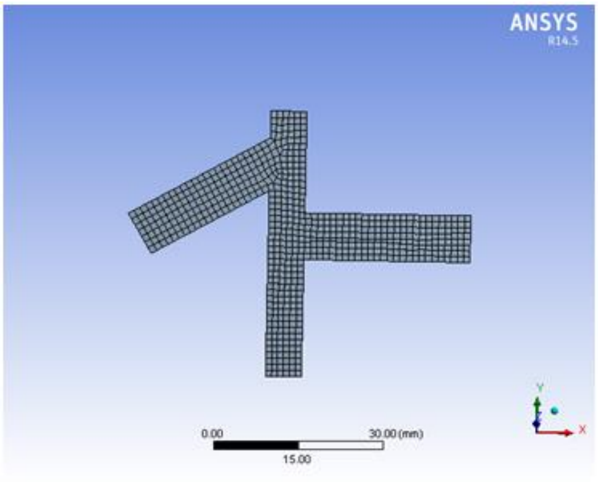
Inlet	-615.42419
Outlet	-20343.316
wall	20958.904
Net	0.16369629

Mass Flow Rate (kg/s)

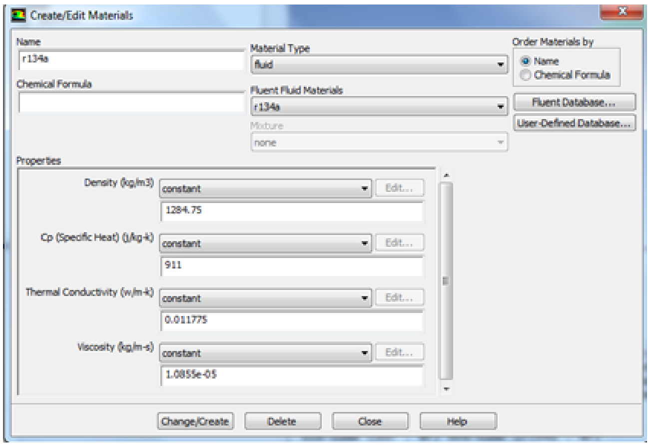
Inlet	1
Interior-_trm_srf	115.30856
Outlet	-0.9999398
wall	0
Net	6.0200691e-05

CFD ANALYSIS OF EXPANSION VALVE

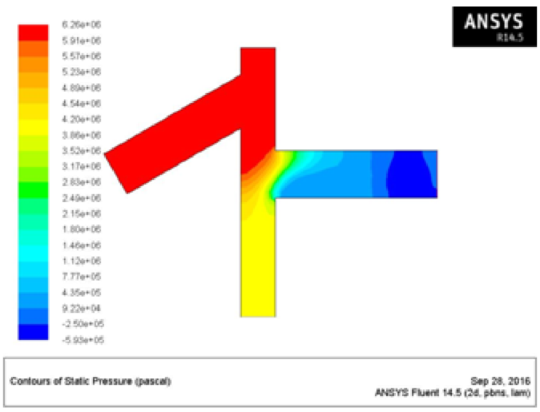
Meshed Model :



Refrigerant R134a:

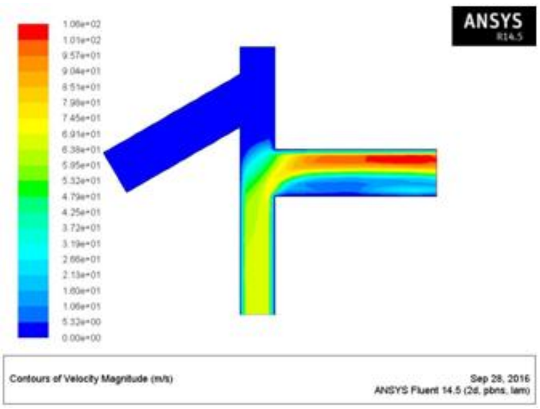


Pressure



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Velocity



RESULTS AND DISCUSSIONS

COEFFICIENT OF PERFORMANCE (COP)& EXERGETIC EFFICIENCY CALCULATIONS

RESULTS TABLE AND GRAPHS OF PRESSURE AND TEMPERATURE AT VARIOUS STAGES

Considering mass flow rate=1 kg/sec (unit mass flow rate)

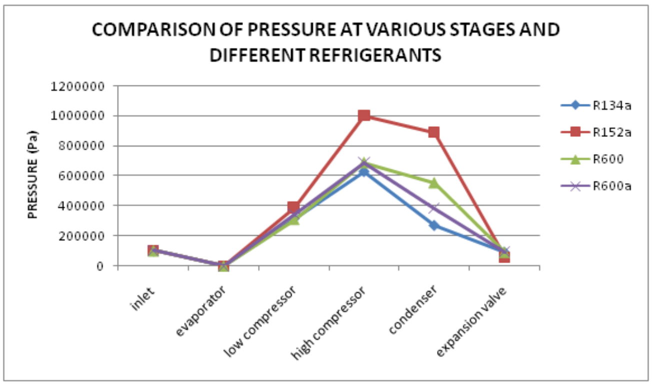
Comparison of pressure (Pa) at various stages

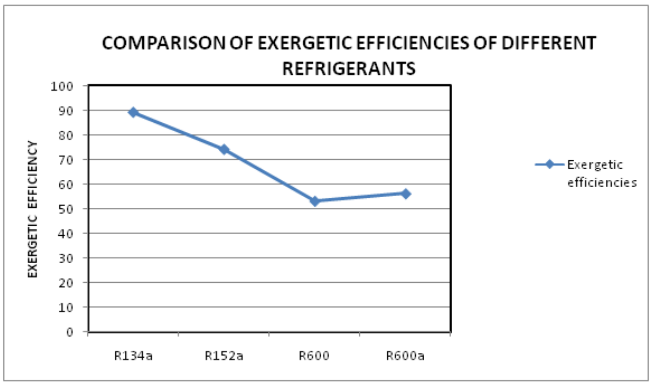
Inlet boundary conditions	Refrigerants	Evaporator Pre. drop	LP compressor (outlet)	HP compressor (outlet)	Condenser (outlet)	Expansion valve
Pressure at 1bar	R134a	119.2190	314341.3	627125	539629	92231
	R152a	140.6767	388804.9	997523	888256	58925
	R600	197.8300	309678.6	686562	552369	91235
	R600a	210.7768	344762.4	686231	584824	93412

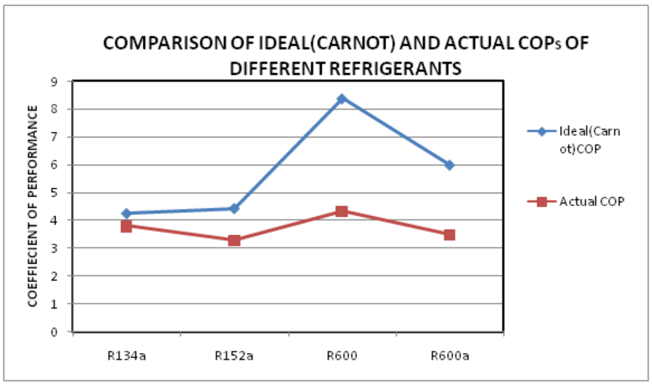
Comparison of outlet temperatures (K) at various stages

Inlet boundary conditions	Refrigerants	Evaporator	LP compressor	HP compressor	Condenser	Expansion valve
Refrigerants boiling pointtemp.s at 1 atm pressure	R134a	290	327	365	232.9	246
	R152a	287	330	372	233.1	249
	R600	299	322	368	233.0	272
	R600a	285	327	370	233.1	261

GRAPHS







CONCLUSION:

In our thesis, we considered five major components such as evaporator, LP compressor, HP compressor, condenser and expansion valve. And also four different kinds of refrigerants are considered such as R134a, R152a, R600 and R600a. 3D models of the two stage vapor compression refrigeration system are done in CREO. CFD and thermal analysis is performed in ANSYS. Comparative analysis of R134a, R152a, R600, and R600a as refrigerants in Two Stage VCRShas been done using finite element analysis to determine the heat transfer rates, pressure loss, and mass flow rates and compared for the refrigerants efficiency. At evaporation stage by considering four refrigerants with same atmosphere pressure and respective boiling temperature of refrigerants, we observe that pressure drop is obtained and temperature is raised in evaporator. R600a obtains low temperature and maximum heat absorption by comparing with different refrigerants. At low pressure compression stage, the boundary conditions of refrigerants are drawn from the evaporator outlet fluid properties and

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

compressed in 110cc compressor. Results shows that maximum pressure and temperature is obtained for R152a (i.e 3.88bar/330K) and minimum pressure for R134a (3.14bar) and min. temperature for R600. At high pressure compression stage, the boundary conditions of a refrigerants are drawn from the LP compressor outlet fluid properties where pressures are same and saturation vapor temperatures taken as input since the temperature decreases (refrigerant cools) in respective intercooler) and compressed in 150cc compressor. Results obtained as max. Pressure raise for R152a and min. for R134a. At condenser stage, the boundary conditions of refrigerants are drawn from the HP compressor outlet fluid properties. By comparing all results of refrigerants in condenser stage maximum heat rejection is observed for R600a.
]
At expansion valve, the pressure is reduced to 1 bar i.e evaporator pressure and temperature is maintained around boiling temperatures of respective refrigerants.
By comparing all refrigerants in the two stage vapor compression refrigeration system R600 is the following advantages: Excellent thermodynamic properties, Actual COP and good compatibility with components and good environmentally friendly (degradable) but energy efficiency observed low as compared to HFCs because of higher boiling points. Since it is extremely flammable therefore the handling and use of R600 series requires adequate safety measures and optimization of models (Dimensions) considered as further recommendations for future improvements. Refrigerants R600 and R600a (Hydrocarbons) gaining popularity since 1990s, and is now a common alternative to hydrofluoric carbons (HFCs) in a number of applications having Zero ozone depletion potential (ODP-0) and very low Global worming potential (GWP-3).

REFRENCES:

- 1. R. F. Neerken, Keys to Compressor Selection, Chemical Engineering, 1979, pp. 17-33.
- 2. Scheel, J. F., Gas Machinery, Gulf Publishing, Houston, 1972.
- 3. Gresh, T., Compressor Performance : Selection, Operation and testing of Axial and Centrifugal Compressors, Butterworth-Heinemann, 1991.
- 4. H. Mak, Handheld Calculator Program Helps Size New Reciprocating Compressors, Oil & Gas Journal, June 25, 1984, pp. 86-89.
- 5. Brown, R. N., Compressors: Selection and Sizing, Gulf Publishing, 2nd ed., 1997.
- 6. Ludwig, E. E., Applied Process Design for Chemical and Petrochemical Plants, Vol. 3, Gulf Publishing, Houston, 1993.
- 7. Avallone, E. A., ed., Baumeister III, T. ed., Sadagh, A. M. ed., Mark's Standard Handbook of Mechanical Engineers, 11th ed., 90th anniversary ed., McGraw-Hill, 2007, pp. -4:27
- 8. Edmister, W. C., Applied Hydrocarbon Thermodynamics, Part 1 & 2, 1985.
- 9. Escoe, K., "Mechanical Design of Process Systems", Vol. 1 & 2, 1986.
- 10. Reid, R. C., Sherwood, T. K., The Properties of Gases and Liquids, McGraw Hill, 1966.

Author's Details:

Eswara Rao.T, (14TU1D2105) Pursuing M.Tech in Thermal engineering from Ellenki Institute of Engineering & Technology, Patelguda, Hyderabad, Telangana, India.

Mrs.V.Saritha, Assistant Professor, Ellenki Institute of Engineering & Technology, Patelguda, Hyderabad, Telangana, India.