Performance Analysis of Window Air Conditioning Test Rig

Vaibhav K. Dongare[1], Siddharth Gurav[2], Prajyot Jadhav[3], Suraj Kamble[4], Swaroop Mayekar[5]

[1] Assistant professor, Department of Mechanical Engineering, Rajendra Mane College of Engineering & Technology, Ratnagiri - 415804, Maharashtra, India

[2,3,4,5] Under Graduate, Department of Mechanical Engineering, Rajendra Mane College of Engineering & Technology, Ratnagiri - 415804, Maharashtra, India.

---***---

Abstract - *This project is related to the future phase-out of hydro chloro fluoro carbons (HCFCs) used in air conditioning system. Most commonly used refrigerant is R22. In field of refrigeration everyone trying to find alternative refrigerants for R-22. Because hydro chlorofluorocarbons (HCFCs) including R-22 is promised to be banned as per the Montreal protocol. Several refrigerants like R290, R407C, R410A, R134a are emerged as substitutes to replace R-22, the most widely used Fluoro carbon refrigerant in the world.*

It is become necessary to replace the R-22 by other refrigerants which are environmental friendly. In this project R-290 (hydrocarbon) is selected as alternative for R-22. Because it has zero Ozone Depletion Potential and almost zero Global Warming Potential. The product is typically at least 97.5% pure with minimal level of critical impurities including moisture and unsaturated hydrocarbons. This make it ideal for use in all type of refrigeration systems.

Key Words: *Alternate Refrigerant, R22, R290, COP, Cooling Capacity, Energy Efficiency Ratio.*

1.INTRODUCTION

In 1974 CFCs were tentatively identified as destructive to the ozone layer. Due to which regular refrigerant R-22 is banned after 2022 for use in refrigeration systems. Hence we select the R-290 (C_3H_8) as alternative have the low GWP (Global Worming Potential) and zero ODP (ozone Depletion Potential).

1.1 Window Air Conditioner

A window air conditioner is a system that cools space to a temperature lower than the surroundings. To accomplish this, heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. During the cycle, a substance called the refrigerant circulates continuously through four stages as shown in Fig1. The first stage is called Evaporation and it is here that the refrigerant cools the enclosed space by absorbing heat. Next, during the Compression stage, the pressure of the refrigerant is increased, which raises the temperature above that of the surroundings. As this hot refrigerant moves through the next stage, Condensation, the natural direction of heat flow allows the release of energy into the surrounding air. Finally, during the Expansion phase, the refrigerant temperature is lowered by refrigeration effect. This cold refrigerant then begins the Evaporation stage again, removing more heat from the enclosed space. Window air conditioner works on the principle of vapour compression refrigeration system. The refrigerant is a heat carrying medium which during the cycle in the refrigeration system absorb heat from a low temperature source and discard the heat so absorbed to a higher temperature sink.

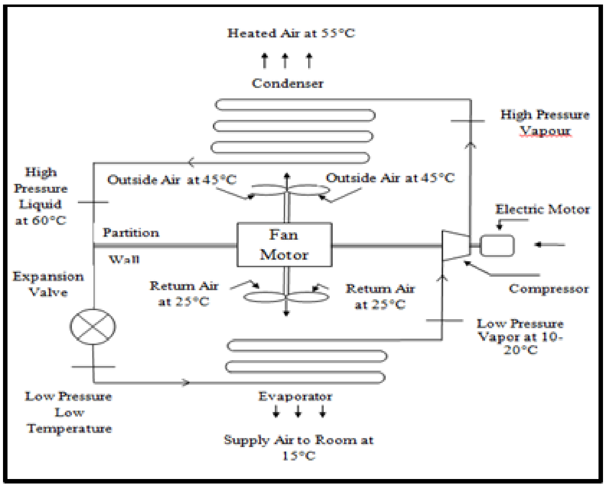

Fig -1: Schematic diagram of Window Air Conditioner

1.2 Effect of CFC's:

Ozone layer in Stratosphere up to 50 km from earth's surface protects us against the harmful effects like skin cancer due to UV rays from sun. Ozone layer absorbs the UV radiations and allows only the beneficial heat rays. CFC gases from different reactions on earth goes to this layer and react with ozone which yields different compounds which is known as Ozone layer Depletion. Reaction of R22 with ozone is as shown below:

$$CH\,Cl\,F_2 \xrightarrow{\text{Sunlight}} CH\,F_2 + Cl$$

$$O_3 + Cl \longrightarrow Cl\,O + O_2$$

Hence Ozone layer depleted to O_2

Solar heat enters through the layer formed by gases emitted from earth and radiated back to space. But as the layer of gases increases heat does not radiated back to space due to which temperature on earth increases which is known as Global Warming. As the CFC refrigerants have chlorine which reacts taking out 100000 O_3 molecules.

1.3 Substitute to CFC's:

The suitability of a refrigerant for a certain application is determined by its physical, thermodynamic, chemical properties and by various practical factors. There is no one refrigerant which can be used for all types of applications. If one refrigerant has certain good advantages, it will have some disadvantages also for a particular application. Hence, a refrigerant is chosen which has greater advantages and less disadvantages.

Although CFC substitutes are of four types i.e. N_2, HCFs & HCFCs, HCs and inert gases but basically hydrocarbons and hydro-fluorocarbons are used as alternative refrigerant to CFC refrigerants. As chlorine atom is absent they have zero ODP and less GWP.

We used R290 as alternative to R22 because

- Both are lower boiling and higher pressure refrigerants.
- They require small displacement compressors.

Hence same compressor can be used.

2. EXPERIMENTAL WORK:

2.1 Test Rig Specification:

A LG company window air conditioner of 1 ton refrigeration capacity was selected to be as a test rig. The unit is having single electricity phase rotary compressor. The condenser and evaporator coils are made of copper with smooth inner tube surface. The interrupted type of fin used in the experiment is very widely accepted method of increasing the heat transfer coefficient and creating more turbulent mixing on the air side of heat exchangers. Both compressor and condenser fins were made of aluminum. The conditioner accommodates a three speed motor to run the condenser and evaporator fans. 'K' type thermocouples are used at five different locations to record the temperature at condenser inlet, condenser outlet, evaporator inlet evaporator outlet and comfort air produced by the window air conditioner at the end of cycle.

Fig.-2: Window Air Conditioning Test Rig

2.2 Refrigerant charging:

Following steps were performed while gas charging:

i. Connect the bottle, vacuum pump to the valve.
ii. Open the valve between vacuum pump and system connection tubes located in the valve block without opening the main valve of the charging cylinder for removing the air inside the system.
iii. After performing this step kept the system idle for few minutes to check any pressure drop because of leakage.

When all the above steps performed correctly, then gas from the bottle is charge into system

3. TEST PROCEDURE:

The performance of test is started with providing electrical supply to Test Rig. Further which the main switch is kept on to have electrical supply to all monitoring devices. System was kept in running condition for at least 10 min to achieve steady state.
The steady state achievement can be obtained by observing the readings given by temperature indicator and pressure gauge. Further Voltmeter and ammeter reading are also taken into consideration. This test is carried out at ambient temperature and pressure conditions. Three different readings were taken for R22 and R290 at different times. The test were carried out at the highest compressor speed by using speed regulator. Different readings taken are as follows:

i. DBT, WBT At inlet and outlet conditions, in ^{0}C
ii. Pressure gauge readings of evaporator (P_1) and condenser (P_2), in psi.
iii. Energy Meter reading, in kWh.
iv. Voltmeter reading, in Volt.
v. Ammeter reading, in Ampere.

4. OBSERVATION TABLE:

After performing the test following observations were recorded:

Table-1: Observation table for R22

Air inlet temperature (^{0}C)		Air outlet temperature (^{0}C)		Pressure gauge reading (bar)		Energy meter reading (kWh)
32.22	24.66	30.55	23.10	3.79	19.35	0.3
32.86	25.27	30.66	23.50	3.65	18.95	0.3
33.14	26.21	31.28	24.68	3.58	18.75	0.3

Table-2: Observation table for R290

Air inlet temperature (^{0}C)		Air outlet temperature (^{0}C)		Pressure gauge reading (bar)		Energy meter reading (kWh)
30.16	24.17	28.39	22.25	3.10	14.47	0.3
31.34	24.80	29.21	22.85	2.96	13.92	0.3
30.68	24.58	28.85	22.56	3.24	15.03	0.3

5. CALCULATIONS:

Calculations for R22 and R290 were made with the help of P-h chart and Psychrometric chart. Sample calculations for first reading are as follow:

5.1 For R22:

Assuming mass flow rate as constant,
m = 0.145 kg/sec

1. Inlet air enthalpy, h_i = 75.5 kJ/kg of air
2. Outlet air enthalpy, h_o = 69.4 kJ/kg of air
3. Enthalpy difference
   $h_d = h_i - h_o$ = 75.5-69.4
   = 6.1 kJ/kg of air
4. Cooling capacity(C.C.) = mass flow rate of air x Enthalpy difference
   = 0.145 x 6.1
   = 0.8845 kW
   = 0.8845 x 3412.14
   = 3018.0370 Btu/hr
5. Energy Efficiency Ratio (EER)
   = (C.C. / Energy Meter reading in Whr)
   = 3018.0370 / 300
   = 10.0601
6. Coefficient of Performance (COP)
   = EER / 3.412
   = 10.0601 / 3.412
   = 2.9485

From Pressure –Enthalpy Diagram, we have
Enthalpy at the start of compression, h_1 = 403 kJ/kg
Enthalpy at the end of compression, h_2 = 446.5 kJ/kg
Enthalpy at the start of expansion, h_3 = 262 kJ/kg
Enthalpy at the end of expansion, h_4 = 262 kJ/kg

7. Capacity of the system = 1.5 TR
   = 1.5 x 3.5 kW
   = 5.25 kW
8. Mass Flow Rate (m) = Capacity in kW/(h_1-h_4)
   = 5.25 / (403-262)
   = 0.03723 kg/sec
9. Refrigeration Effect (Re) = m x ($h_1 - h_4$)
   = 0.03723 x (403-262)
   =5.2494 kW
10. Compressor work (W) = m x ($h_2 - h_1$)
   = 0.03723 x (446.5-403)
   = 1.6195 kW

11. Heat rejected in the Condenser (Q_h)

= m x (h_2- h_3)

= 0.019944 x (446.5-262)

= 6.8689 kW

12. Co- efficient of Performance (C.O.P.)

= (h1 – h4) / h2 – h1)
=(403–262)/(446.5-262)

= 3.24

5.2 For R290:

Assuming mass flow rate as constant, m = 0.150 kg/sec
Assuming mass flow rate as constant,
m = 0.150 kg/sec

1. Inlet air enthalpy, h_i = 73.4 kJ/kg of air
2. Outlet air enthalpy, h_o = 65.8 kJ/kg of air
3. Enthalpy difference
$h_d = h_i – h_o$ = 73.4-65.8
= 7.6 kJ/kg of air
4. Cooling capacity(C.C.) = mass flow rate of air x Enthalpy difference
= 0.150 x 7.6
= 1.14 kW
= 1.14 x 3412.1
= 3889.8396 Btu/hr
5. Energy Efficiency Ratio (EER)
= (C.C. / Energy Meter reading in Whr)
= 3889.8396 / 30
= 12.9666
6. Coefficient of Performance(COP)
= EER / 3.412
= 12.9666 / 3.412
= 3.8

From Pressure –Enthalpy Diagram, we have
Enthalpy at the start of compression, h_1 = 570 kJ/kg
Enthalpy at the end of compression, h_2 = 630 kJ/kg
Enthalpy at the start of expansion, h_3 = 306.66 kJ/kg
Enthalpy at the end of expansion, h_4 = 306.66 kJ/kg

7. Capacity of the system = 1.5 TR
=1.5 x 3.5 kW
= 5.25 kW
8. Mass Flow rate, m = Capacity in kW/(h_1-h_4)
= 5.25 / (570-306.66)
= 0.01994 kg/sec
9. Refrigeration Effect (Re) = m x (h_1 – h_4)
= 0.01994 x (570-306.6)
= 5.2498 kW
10. Compressor Work (W)
= m x (h_2 – h_1)
= 0.0243 x (630-570)
= 1.1976 kW
11. Heat rejected in the Condenser (Q_h)
12. = m x (h_2- h_3)
= 0.019944 x (630-306.66)
= 6.4538 kW
13. Co- efficient of Performance (C.O.P.)
= (h1 – h4) / h2 – h1)
= (570 – 306.66) / (630 – 570)
= 4.389

Table-3: Result Table for R22

Mass flow rate(m), kg/s	0.03723	0.03697	0.03658
Refrigeration effect, kW	5.2494	5.2497	5.2493
Compressor work, kW	1.6195	1.6297	1.5912
Heat rejected (Q_h), kW	6.8689	6.8764	6.8404
$COP_{theoretical}$	3.24	3.2272	3.2988
Cooling capacity, kW	0.8845	0.8990	0.9280
Energy efficiency ratio	10.0601	10.2250	10.5548
COP_{actual}	2.9485	2.9967	3.093

Table-4: Result Table for R290

Mass flow rate(m), kg/s	0.01994	0.02022	0.02082
Refrigeration effect, kW	5.2493	5.2491	5.2491
Compressor work, kW	1.1976	1.2233	1.2498
Heat rejected (Q_h), kW	6.4538	6.4724	6.4989
$COP_{theoretical}$	4.389	4.2909	4.064
Cooling capacity, kW	1.14	1.155	1.08
Energy efficiency ratio	12.9666	13.1367	12.2837
COP_{actual}	3.8	3.859	3.60

6. COMPARISON OF R22 AND R290

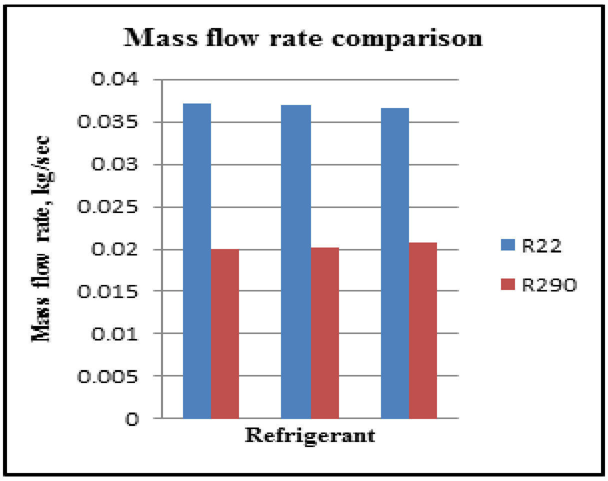

Chart -1: Mass flow rate comparison

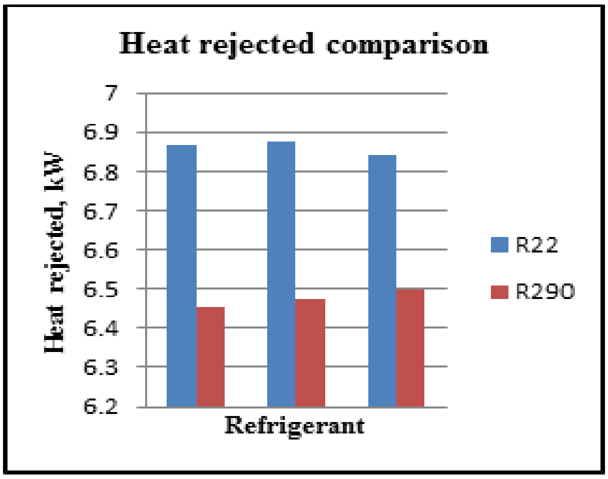

Chart -4: Heat rejected comparison

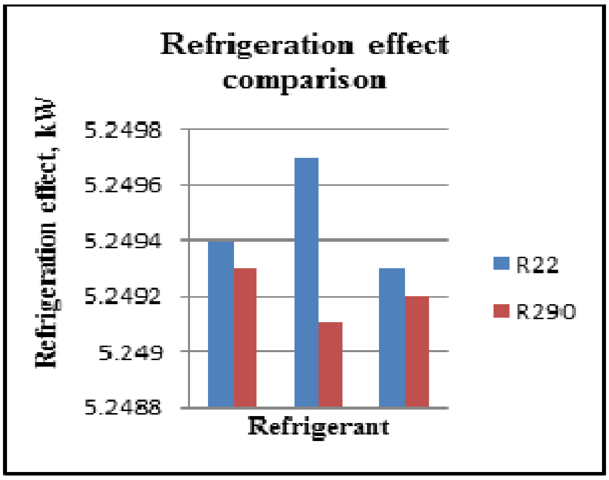

Chart -2: Refrigeration effect comparison

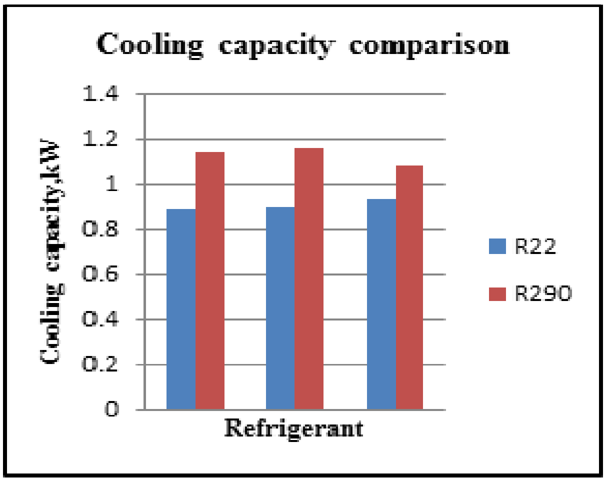

Chart -5: Cooling capacity comparison

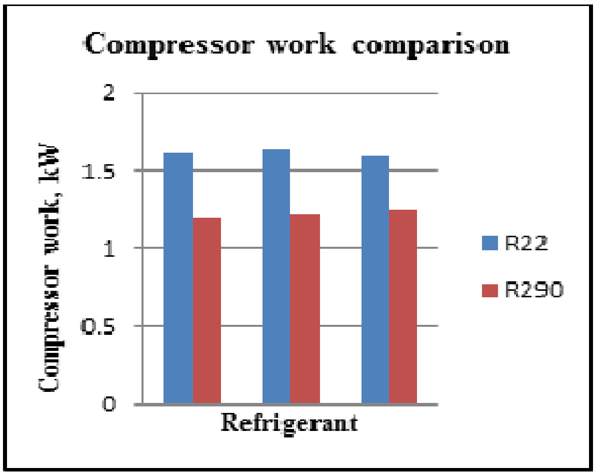

Chart -3: Compressor work comparison

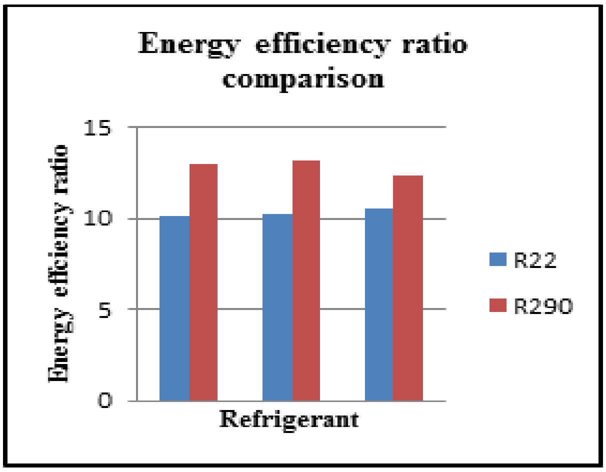

Chart -6: Energy efficiency ratio comparison

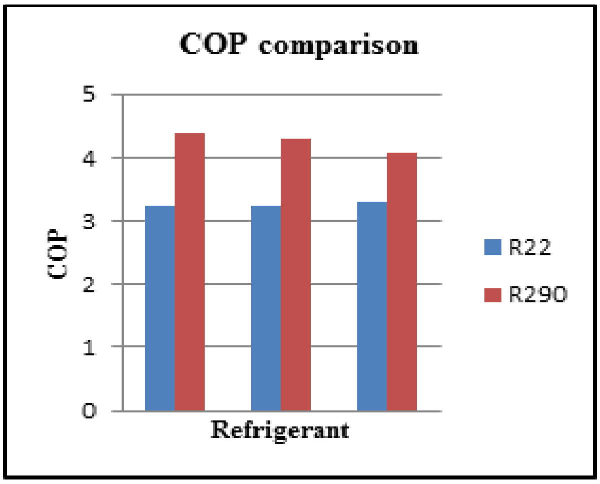

Chart -7: COP comparison

7. CONCLUSIONS

1. The Energy consumption of Window AC is 20-25 kWh/d/NPT for R290 and 25-30 kWh for R22 kWh/d/NPT
2. **Compressor Power**: The compressor power required per ton to drive the system is smaller for R290 when compared with R22 taken on average basis.
3. **Compressor Ratio**: Compressor ratio is lesser for R290 when compared with R22 taken on average basis.
4. **Refrigerant Mass flow Rate:** The refrigerant mass flow rate per ton is less for R290 when compared with R22 taken the average of readings.
5. **COP**: The Co-efficient of performance of the system for R290 is higher as compared to R22 taken the average of readings. It is observed that COP of R290 is 1.25 times greater than COP of R22.
6. **Cooling Capacity**: The Cooling Capacity of the system for R290 is better as compared to R22 taken the average of readings.
7. **Energy Efficiency Ratio**: The Energy Efficiency Ratio of the system for R290 is higher as compared to R22 taken the average of readings

ACKNOWLEDGEMENT

We would like to express our sincere gratitude towards our guide, Prof.V.K.Dongare for the help, guidance and encouragement. This work would have not been possible without his valuable time, patience and motivation. We thank him for making our stint thoroughly pleasant and enriching. We are deeply indebted to H.O.D. of Mechanical Dept. Prof.S.R.Bhandari and Prof.A.R.Suware. They supported us with scientific guidance, advice and encouragement, it was always helpful and enthusiastic and this inspired us in our work.

REFERENCES

[1] M.Ashok Chakravarthy, M.L.S.Deva Kumar. "Experimental Investigation of an Alternate Refrigerant for R22 in Window Air Conditioning System," International Journal of Scientific and Research Publications, Volume 2, ISSN 2250-3153.

[2] [1]K. John Samuel, [2]K. Govindarajulu and [1]G. Edison. An "Experimental Investigation and Performance Evaluation of 1.5 TR WindowAir-Conditioner by Using R22, R407C and R410A by Varying the Capillary Pitch," World Applied Sciences Journal 29 (11): 1468-1472, 2014,ISSN 1818-4952,© IDOSI Publications, 2014, DOI: 10.5829/idosi.wasj.2014.29.11.1706

[3] Prof. S.M.Shaikh[1], Prof. A.M.Patil[2], Prof. A. M. Vibhute[3]. "Performance Investigation of Window Air Conditioner," IOSR Journal of Civil and Mechanical Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 32-37.

[4] Madhu Jhariya[1*], P.K.Jhinge and R.C. Gupta[2]. "Experimental stedy on performance of condenser of two different types used in Window Air Conditioner," Int.J.Curr.Res.Aca.Rev.2013;1(4):35-41

[5] M Sidhartha Bhatt and R Sudhir Kumar. "Window Air Conditioners: Evaluation and Energy Conservation," Journal of Scintific & Industrial Research, Vol.60, August 2011, pp655-661

[6] Sheik Ismail THARVES MOHIDEEN[a] and Nagachari NETHAJI[b]. "Experimental Studies on Improvement of COP of Window Air Conditioning Unit," [a]Department of Mechanical Engineering, Institute of Road and Transport Technology, Erode, India. [b]Department of Mechanical Engineering, DDCSM Polytechnic College, Palacode, India.

[7] K. R. Aglawe[#1], M. S. Matey[#2], N. P. Gudadhe[#3]. "Experimental Analysis of Window Air Conditioner using Evaporative Cooling," International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 2, February- 2013 ISSN: 2278-0181

[8] J. Paul Guyer. "An Introduction to Air Conditioning System Design" by, P.E., R.A., Fellow ASCE, Fellow AEI, 2009

[9] Dr. Robert Hammon, "HVAC DESIGN GUIDE," California Energy Commission, Public Interest Energy Research (PIER) Program, JULY 2005.

[10] "Refrigeration and Air Conditioning" , 3rd Edition, by C. P. Arora, The McGraw-Hill Companies

BIOGRAPHIES

Prof. Vaibhav K. Dongare. Work Profile: Assistant Professor Department of Mechanical Engineering, Rajendra Mane College of Engineering and Technology.

Mr. Siddharth P. Gurav. Student of Mechanical Engineering. Work Profile: working on a Design and Fabrication of Window Air Conditioning Test Rig.

Mr. Prajyot J. Jadhav. Student of Mechanical Engineering. Work Profile: working on a Design and Fabrication of Window Air Conditioning Test Rig.

Mr. Suraj S. Kamble. Student of Mechanical Engineering. Work Profile: working on a Design and Fabrication of Window Air Conditioning Test Rig.

Mr. Swaroop P. Mayekar. Student of Mechanical Engineering. Work Profile: working on a Design and Fabrication of Window Air Conditioning Test Rig.