

# Car Air Conditioning Systems Expectations / Limitations / Emerging Trends

# CAR AIR CONDITIONING SYSTEMS

## EXPECTATIONS / LIMITATIONS / EMERGING TRENDS

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The general expectation, if asked, as to what an ideal Car Air Conditioner should achieve is to make human body thermally comfortable while keeping glass areas fog / mist free.

If we go in to specifics, the requirements become more subjective & many other aspects crop in.

The requirements then can be further broken in to the details such as :

- a. Initial fast cool down, in a hot vehicle.
- b. Enough air circulation to all occupants without causing uncomfortable drafts or suffocation.
- c. Uniform maintenance of temperature in the entire occupied area without noticeable temperature gradients.
- d. Satisfactory temperature in all weather conditions in all seasons and over all driving conditions like city traffic or highway driving.
- e. The system must be quiet, no undue disturbance felt due to irritating noise especially when using music system.
- f. The vibrations should not be felt in any part of vehicle like Dash board, floor gearshift etc or get transmitted to passenger compartment when A.C. is switched on.
- g. No undue jerks or loss of engine power when A.C. compressor cuts in or cuts out while clutch engaging / disengaging.
- h. Controls easy to understand & operate without affecting the drivers concentration.
- i. Must be energy efficient system without excessive additional fuel cost.
- j. Should not affect vehicle engine / radiator cooling performance especially at a time of accelerating or driving at low speeds or while climbing gradients.
- k. And last but not least the A.C. system should be cost effective.

~~As a system designer, this puts lot of restrictions on the options available to him~~ and it is therefore essential to define at the start of the project, the areas which the vehicle manufacturer wants importance to be attached and define requirements that are less critical.

In any design, one would appreciate, it is always a trade off, if one wants to gain something you should be willing to sacrifice some other features.

The A.C. designer does not have a luxury of availability of air flow areas or geometries described in text books or as can be recommended on new building construction projects at the start up. The pressure drop in Air ducts are significant.

Here in automobile field, he has to negotiate styling's requests for aesthetic AC outlets & control appearance,

The evaporator / blower / heater unit has to be located in such a manner that it should not be visible to driver / co-passenger and at the same time must operate with a much narrow and twisting duct work that is far from any ideal design requirements.

The engineer has also to package the compressor, its drive, plumbing, condenser & its fan in a hot restricted space, without overlooking maintenance / ease of service requirements.

While selecting compressor and its speed, he has to ensure that compressor uses minimum engine power and be efficient over a wide range of RPM.

Keeping all these issues in mind, he cannot afford to forget the cost aspect and has to package the system and selection of components to meet the targeted costs.

He also has to be prepared to incorporate design changes during first phase of vehicle launching which are a norm with most automobile manufacturers especially with regard to routing of piping and compressor and other mounting brackets.

The designer has to consider effective A.C. operation in

1. cool down
2. city traffic
3. highway
4. idle and
5. gradient mode operations

Now going in to further more specific issues, the A.C./ designer must take into consideration following.

1. The complete range of performance of the compressor for all speeds at which it will be driven for all ranges of suction and discharge pressures it is likely to encounter.

2. The performance map of evaporator for all air quantities in different fan modes, air temperatures and evaporation temperatures. Especially ensuring that evaporator icing problems are never to be encountered.
3. The complete performance characteristics of the condenser over full range of air quantity provided.
4. The performance interaction between individual components of the system over the full range of operation. It should be remembered that the system is as powerful as its weakest component.  
**Capacity is not determined by any one component, but a change in any component affects the system balance capacity.**
5. The free draining of condensed moisture on the coil to avoid accumulation in the evaporator box thereby spilling on the floor carpet and or generating stinking smell fungus / bacterial formation.
6. Keeping evaporator coil clean by way of filters / wire mesh to ensure dirt / dust / leaves / rats and other pests / insects preventing from entering the A.C. unit.

**What are the possible trade offs ?**

1. It should be remembered that air is a medium which picks up heat from car cabin & brings it to evaporator coil for heat rejection. In the process, air gets cooled & is circulated through passenger cabin to provide comfort. This means more the air flow, faster is the cooling & more uniform temperature in all parts of interior space, without hot or cold spots.

Similarly, only large air volume at higher temperature will not do as it would not produce desired comfort condition.

This means large volume of air at lower air temperature from coil will be more preferred system for faster cool down & lower cabin temperatures.

2. As discussed earlier, there is then some trade off. A higher air flow would mean higher noise level. It could be beyond acceptable limit & hence a compromise has to be done between air flow & noise level. A rule of Thumb could be 100 to 150 litres / sec approx. air quantity depending on vehicle interior volume & noise level below 68 db.

Similarly, a lower air temperature around  $4^{\circ}$  C would mean evaporator coil temperatures nearing freezing point of  $0^{\circ}$  C & chances of coil freeze up / ice formation increase.

2. Ice formation must be avoided at all costs. Since if ice formation tendency starts, due to blockage of coil, the air quantity starts reducing, there is less surface area available for heat transfer & hence less cooling capacity leading to further drop in evaporating temperature & increased ice formation. Once ice formation starts, one cannot stop it unless the system is shut down. It is called snow balling effect & can choke the coil completely leading to no air flow.
3. Many would have observed this phenomenon especially with after-market under-slung kits & passenger feels air conditioner wiring is burning, since smoke coming out is noticed at air outlets. It is nothing but air with suspended frost. The cooling also suffers. If driver switches off A.C. for 15 – 20 minutes, allowing coil to melt all ice, the A.C. then starts functioning normally. An average grill temperature of 6-9 degree is ideal which ensures that coil performance is in safe range & no danger of ice formation exists. Hence feeling of lower temperature at grill could be a misleading situation. What one must look for is lower grill temperature without affecting nominated air flow, which means coil is not icing & blocking air flow. **Only lower grill temperatures without adequate air flow will not lead to passenger comfort as the required temperature cannot be reached without sufficient air.**

The other danger of operating at low evaporating air temperature is the thermostat would tend to clutch / de-clutch compressor very frequently if the compressor has not been selected properly & is oversized for the duty.

4. The selection of compressor speed is important. If most of the driving is in city traffic conditions, a higher pulley ratio may help so as to get higher compressor speed when engine is near idling speed.

The danger however is, if the same vehicle is running on highway, it may lead to excessive compressor RPM beyond recommended limits, reducing the life of compressor due to extra wear. As against this, if one designs the pulley ratio keeping highway operation in mind, the cooling performance gets adversely affected in city traffic conditions due to inadequate cooling due to lower engine / compressor speeds.

Sometimes this is taken care of by fast idle speed arrangement, but if the engine power is inadequate at idle speed, the engine struggles to take compressor load. Most of the drivers experience this, especially with the cars having engines with lower horse power / displacements.

A choice however has to be made in the beginning as you never know who is going to buy the car & where it is going to be operated for most of the time, leading again to some trade off.

5. Another most important factor to be remembered is the cooling load is not constant and varies depending on many factors like, ambient temperature / humidity conditions, occupancy / glass area / insulation of the body & dash board, fresh air requirement / colour of car etc. The requirement is also highest when vehicle is standing in open under the direct impact of solar rays.

The soak temperature inside the vehicle could be higher than ambient temperature by 25 to 30<sup>o</sup> C.

The air conditioner provided must therefore achieve fast cool down and also be able to meet lower heat load requirement on steady drive conditions, without constant cycling.

The car A.C. compressors normally do not have any capacity control arrangement unlike compressors for land installations, where capacity of the system can be reduced by cylinder unloading or switching on / off one or more compressors in multi compressor installations or many other capacity control methods.

In car A.C., the only parameter to which compressor responds is Air On or Off temperature from evaporator coil. When desired temperature is reached, the thermostat declutches the compressor thereby shutting off cooling which leads to increase in occupied space temperature, again cutting in compressor giving cooling. Thus the compressor either gives full capacity or no capacity at the operating speed and as can be expected, selection of an oversized compressor would lead to more frequent on / off operation reducing the life of clutch / compressor and putting undue stresses on engine.

The load pattern and compressor output which is dependant on vehicle speed are therefore totally independent in automobile operation. If load is high and if you are driving at lower speed system cooling performance is adversely affected.

Similarly if the load is low, and you are driving a higher speeds, the compressor and system is delivering much higher output than needed and the system will constantly cycle on / off.

This phenomenon is noticed when, due to sudden acceleration / deacceleration A.C. compressor gets engaged / disengaged, leading to jerky operation.

On many occasions we experience that while overtaking, we are expecting certain engine performance & if at the same time if A.C. compressor cuts in we feel sudden momentary loss of power due to extra compressor load especially on smaller horsepower vehicles and visa-a-versa. This is due to A.C. system operation is controlled by temperature alone and engine / compressor speed is dependant on driving conditions.

The foregoing analysis shows that the wide range of compressor capacity caused by varying speeds and carrying operating conditions require some means of control to maintain good capacity during pull down and road driving conditions, and yet to prevent coil icing up during highway operations.

The ideal situation would be to have the compressor capacity always matching with cooling requirements of the car without the use of a cycling clutch or any other device.

Some compressor manufacturers provide variable displacement compressor designs with automatically adjustable capacity.

When the demand is high the compressor works with full stroke. As the cooling load requirement diminishes, the compressor starts to destroke thereby reducing the compressor output to match the requirement. This thus eliminates the need of compressor thermostat cutting clutch Off / On . the advantages of variable displacement are significant by way of smoother ride / passenger comfort and reduced fuel consumption & power required to drive the compressor and less wear.

Since we are on compressors let us find out what are the currently used technologies. Majority of car air conditioners use reciprocating compressors, These could be wobble plate / swash plate design with inline pistons. The compressor could be fixed displacement or variable displacement as mentioned above.

The other types of compressors are Rotary design / Scroll designs.

The Rotary / Scroll compressors are more compact compared to reciprocating compressors, lighter in weight, less noisy and consume less power.

The latest trend is therefore to switch over to scroll compressors, the only drawback being they are still more expensive compared with other types. Most of the compressor manufacturers in the world are currently engaged in development of scroll compressors and as the volumes would increase the cost will come down.

The other major components are evaporators / condensers and these heat exchangers are available in tube and fin design, serpentine, parallel flow & plate and fin designs. The efficiencies as well as costs go on increasing in the same order.

The expansion device is 4<sup>th</sup> major component without which no A.C. system would function. The types available are, Orifice tube, Thermostatic expansion valve, Block valve, Electronic expansion valves operating with PLC's. Here again the performance & cost goes on increasing in the same order. As the cost of electronic components is falling, the more & more use of electronic controls would be obvious in future.

A separate / independent article would be required to be presented if one wants to go into more details about A.C. system components and their specialties.

We would now conclude this article by touching upon some of emerging trends / future technologies and the areas in which the designers / scientists are currently working globally.

The CFC refrigerants contributing to ozone depletion were banned with adaptation of Montreal Protocol in 1987 & resulted in subsequent phasing out of CFC's in developing countries.

The automobile industry predominantly have adopted HFC 134a as a choice refrigerant for air conditioning systems in place of CFC 12.

The lobby of environmentalists are also suggesting phasing out of these new refrigerants due to their global warming potential. The Kyoto protocol includes R134a in its basket of reexamination of these gases & hence study of alternative refrigerants in place of R134a for automotive air conditioning is assuming greater importance.

The R134a has global warming potential (GWP) of 1300, implying that if it leaks, it is equivalent to leaking 1300 times the same amount of Carbon dioxide.

The new refrigerants & gases are now evaluated on the basis of ( TEWI ) Total Equivalent Warming Impact index for comparison & attempts to use natural refrigerants is gaining renewed interest.

Many car A.C manufacturers are studying use of CO<sub>2</sub> as a refrigerant. CO<sub>2</sub> systems operate at significantly higher pressures ( 5 times higher than R134a ) systems & would demand new compressors to withstand these pressures. It would also demand higher quality fittings to eliminate leakage. Leakage due to elevated levels of CO<sub>2</sub> can also affect the comfort & health of driver & vehicle occupants.

Scientists / Engineers are working on these issues & it is expected that in 5 – 10 years time, the systems would be perfected. Extremely thin yet very strong aluminum tubing can be made available to replace heavy steel tubing. Such tubing has already been developed. The system would become much more compact compared to existing systems.

The consortium in Europe is working on project RACE for car air conditioning using CO<sub>2</sub> as refrigerant.

The other natural refrigerants like air, HFC's or even water are being explored to replace conventional refrigerants in stationery & mobile air conditioning applications.

Scientists in US also believe that they are close to developing a cooling system for vehicles based on magnetic refrigeration. This is based on magneto caloric effect. The ability of some metals to heat up when magnetized and cool down when removed from magnetic field.

The air conditioning using this system would run on electrical power produced by alternator thus reducing load on powertrain & making car more efficient. The process can also be reversed in order to heat the vehicle.

This technology is ideal for use in electrical cars.

TI Group in Europe is working on Automotive systems using concentric tube. The patented design of this new, two in one tube, called the co-tube, offers significant benefits to vehicle manufacturers.

The normal system uses supply & return pipes to carry pressurized liquid & vapour refrigerant & with the limited space, packaging becomes problematic many times.

This type of plumbing would save space, reducing packaging & improve performance, strength & flexibility.

The Chrysler's Jeep Cherokee, already uses this Technology & more would follow.

The new research also is tending to conclude that in automotive systems, when HFC R134a is used in place of CFC R12, it may not be necessary to change mineral oil with PAG / POE oil. Retaining mineral oil with HFC R134a does not prove to be harmful & in fact it has many advantages, like better lubricity, less hygroscopicity lower chemical reactivity, less cost etc.

The upgradation of major components with latest technologies will be another subject, as mentioned earlier. Compressor designs are undergoing changes like variable displacement reciprocating & scroll compressors. Increased use of Scroll technology being preferred by automobile manufacturers. Development of orbital Vane Rotary compressors etc is also being attempted. New heat transfer areas to make heat exchangers more compact, more silent blower, new refrigerants, alternate technologies & increased use of electronic controls would be future ingredients of automobile A.C. systems.

The heat exchanger Technology is also going through rapid changes & increased use of Plate heat exchangers is finding its way in not only stationary applications, but also in mobile field.

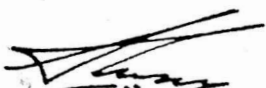
The controls are changing from manual to electrical to electronic systems especially with the rapid process in electronic field, expansion valves using PIC controllers costs are coming down rapidly & can become a norm.

The developments are taking place so rapidly that it may not surprise a new Technology never thought of before may become popular in the near future & therefore investment in new Technology R & D activity is a must if one wants to retain & remain in the forefront as mobile air conditioning system manufacturer.

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