Bus Air Conditioning

Lecture No.5

BUS AIR CONDITIONING

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APPLICATIONS:

The air conditioning applications for transport sector includes all mobile equipment, like passenger cars, bus air-conditioning, truck refrigeration, mobile homes (house on wheels) mobile electronic testing vans, tanks, containers, air crafts, space ships, defense shelters, fishing trawlers, ships, railways, mobile cranes, off highway equipment or any other special requirements.

This presentation deals mainly with bus air conditioning requirements. standards, specifications, and various parameters which the body builder should consider while constructing air conditioned buses with particular attention to air management and insulation.

INDIAN SCENARIO:

The air conditioned buses manufactured in India were introduced in early 80's. The policies of government and the duty structures, at that time, were not conducive for rapid growth of this segment and this sector therefore had hardly any growth in the decade. The realisation of requirement of air conditioning for buses as essential prerequisite for tourism and for improving general comfort of passengers started getting due attention in late 80's and early 90's. Till such time there was only one manufacturer in India producing units in collaboration with German technology. Other leading manufacturers who tried to assemble and produce bus air conditioning equipment from the available components used for land installations did not succeed as design of mobile equipment requires special attention and materials, components which are much different than those, successful for land applications.

Presently the leading manufacturers all over the world, of this specialised equipment have entered India, which itself indicates that globally it is recognised that this segment is going to grow very rapidly as compared to other industrial products. This is evident from the fact that in 80's hardly 10% cars were air conditioned and there was no manufacturer giving factory fitted car air Conditioners.

Today practically 30 to 40 % cars are air conditioned and all the leading world manufacturers putting their plants in India are giving AC as factory fitted option.

BUS CHASSIS MANUFACTURERS:

In India as on date there is not a single manufacturer who produces chassis exclusively for buses. The two leading manufacturers are truck chassis manufacturers who build bus chassis as well by carrying out modifications in suspension mechanism and other minor changes.

The total chassis manufactured for large size trucks and buses together is around 150000 per annum, out of which around 30000 are used for converting and constructing buses and remaining for goods transport. The air conditioned buses build every year do not exceed 500 per year. This also includes contribution of small manufacturers who build 2 to 3 air conditioned buses in a year.

Demand for air conditioned buses is increasing rapidly due to four major factors:

1. Duty structure has been rationalised to a great extent over last 3 years although much needs to be done still. The cost of A/C equipment is nearly 30 to 35% of total bus cost in India as against 5 to 10% elsewhere in developed countries.

2. Many state governments have made it mandatory that tourist bus operator must fit A/C unit, then only they are eligible for operating and the licenses are issued on this basis.

3. Once any tourist operator introduces A/C bus on a popular route, the tourist then give preference to air conditioned travel over normal bus and other tourist operators have to follow the suit if they have to remain in that particular market segment and retain their share.

4. Consumers/Passengers have started realising the benefits for A/C travel and as the paying power is gradually increasing the demand for such A/C travel is increasing in geometric proportions, since commuters can see that by paying little extra amount they are able to reach destination in as fresh a condition as when they started their Journey without spoiling their clothes and without exposing themselves to pollution hazard like dust, smoke etc. The efficiency also improves as they are fresh and less exhausted when they reach destination.

THE PRESENT BUS A/C SCENARIO:

The Indian market is divided in three major segments

1. Small buses up to 10 to 15 passenger carrying capacity used by corporate world for commuting their executives from residences to place of work, Airport shuttles, Hotel vans, Ambulances and other specific needs.

2. Medium size buses up to 18 to 25 passengers mainly called as LCV's. These buses are also predominantly used for inter-city operations as mentioned above and some of them are also used for between the city operations on small distance travel, for tourist travel.

3. Large buses carrying 38 to 45 passengers mainly used over long distance travel for tourism and for inter city operations for mass transport in metropolitan cities.

The small and medium bus air conditioning requirements are met by integrated units using independent components. Condensers are either roof mounted or skirt mounted although first option is more popular in India due to bad road conditions and dusty atmosphere, water flooding etc., which tends to make condenser very dirty in a short time. The evaporator section is normally mounted at the back, suspended from the roof, and compressor is driven by main engine. This leads to compressor and correspondingly the unit changing its capacity constantly as the engine speed fluctuates from idling to full speed. The evaporators can be either ducted or free blow type. In short, the system is more or less identical to car A/C systems, but of bigger capacity.

Further part of this presentation deals with finer aspects of bus body construction and air management for large bus segment and compares with international practices as this is the potential growth area from tourism point of view.

The most important difference between Indian buses and buses used abroad lies in main engine power. In USA, Europe, and most of the Asia Pacific countries engines of having horse power in excess of 250 HP are used. This enables the air conditioning compressor to be run from main engine as the engine Performance does not deteriorate when A/C compressor takes 25 HP out of it for running A/C system. The system therefore then becomes similar to car or medium size buses except for the capacities.

This is not possible in India, as both our chassis manufacturers have engines fitted on tourist buses of less than 130 HP. The main engine power is therefore inadequate to spare power for A/C unit, which requires approx. 25 HP. It becomes therefore essential to install separate power pack for driving refrigeration compressor utilizing separate diesel engine. This naturally, adds cost, noise, and additional vibrations associated with it. The system also becomes complicated as regards wiring, electrical panels, etc. Although manufacturers have plans to upgrade the engine power in the range of 180 to 200 HP. It is understood that these would be used mainly for trucks carrying cargo as they see no benefit in putting larger horse power engines for passenger buses, the contention being it would not reduce travel time looking at the heavy traffic on roads and bad road conditions, but on other hand would add to the fuel cost which the bus operators would be reluctant to bear.

Power pack therefore becomes unavoidable for large A/C buses and necessary expertise in designing reliable unit with silent engine, reliable alternator, compressor drive components such as electromagnetic clutch, noise shield etc. have to be engineered for which less technology is available from partners abroad who do not use such equipment extensively. Power pack requirement exists in countries mainly, China, India and few Asian countries and India could serve as a leading supplier globally for such equipment.

As there are no chassis manufacturers in India producing bus chassis exclusively, there are also no body builders, who have necessary expertise to build air conditioned coaches, hence this presentation now deals on this aspect.

The technology in constructing leak proof body with properly sealed windows, and air management are some of the aspects discussed.

The Indian fleet owners and therefore body builders prefer partition between passenger compartment and driver's cabin, thus depriving the driver air conditioned comfort, due to wrong notions that drivers are likely to fall asleep if they are given more comfort than they are used to it. Another reason put forward is that the driver and his colleague needs privacy. The third reason is they require partition for supporting video/TV monitors. This practice is not followed elsewhere in the world and the system needs to be designed to cool entire bus than only the passenger compartment.

The another major difference is the units now available world over are using environmental friendly refrigerants like R-134a, R 404a in place of R 12 or R 502. The CFC refrigerants are banned in developed countries as per Montreal Protocol agreement from December 95 for use in all new equipment. In India we are allowed to use R 12 up to 2010 being developing country, and it seems that unless we are driven to the limit or forced by legislation internally, we may not switch over to new refrigerants so soon. The reluctance of Indian refrigerant manufacturers is also a major contributing factor. Because of governments liberalization policy, the multinationals entering into the country are pressurising Indian users/ manufacturers to use new refrigerants and this could be the major reason for earlier switch over. The high pressure refrigerant R 22 is continued to be used, however the entire transport industry globally is shifting towards R 134a as a refrigerant of choice.

The use of new refrigerants require special expertise, special materials for hoses, rubber components, compressors, and special controls, fittings to make system leak proof besides needing new type of oils.

Coupled with this skilled, trained manpower is also essential to attend to installations/ field servicing, more or less on similar lines as boiler attendant certification.

This skills need to he developed speedily if we decide to hasten the switching over to new refrigerants and lot of training efforts would go into it.

The air conditioning cooling requirements are given applicable for standard Indian buses in the annexture, however these vary vastly depending on various factors such as type of application, bus body construction, ambient conditions. operating hours, etc. and detailed user friendly computer programs are available to arrive at reasonably accurate cooling load estimates.

The typical specifications and requirements are also spelled out in detail in the annexture enclosed.

We shall now deal in more details as to the additional precautions, the body builder should take while constructing A/C bus.

The foremost objective of the body builder should be to minimise heat ingress inside the bus so that an A/C system is not overburdened.

If the analysis is done, as to which are major contributors, it can be seen that engine heat ingress, outside air leaking in and proper roof and flooring insulation becomes top three items on which the body builder should concentrate.

1) The engine heat ingress can be substantially reduced by spraying PUF foam on the under side of the bonnet. In addition it is also essential many times to provide insulated canopy, so that radiated heat ingress is minimized. In India no body builder uses these methods presently, the major body builders should procure equipment needed to spray PUF which will help in better working of the A/C unit.

2) The construction of bus body should be such that it is made leak proof/air tight. One does not readily realises the importance of this but when the bus is traveling at average speed of 50 miles an hour, even a small slit or crack becomes equivalent to 6 ft. long slit allowing outside air quantities as high as 1400 cft. which is in reality higher than air ingress due to door openings. Air infiltration is more pronounced when vehicle is in motion. This outside air adds additional heat load not taken into account and disturbs the efficient working of the cooling system.

3) The bus body after construction can be tested for leakproofness by water spray method or smoke test method.

4) Particular attention must be paid to make door airtight, using requisite gasket materials and better workmanship compared to non A/C buses.

5) Out of total solar heat gain, the roof contributes maximum load, hence roof needs to be insulated with at least 50 mm thick PUF insulation, whereas for the entire bus 25 to 37 mm insulation should suffice. The flooring also needs special additional treatment since solar reflection from roads affects floor more than exterior walls. A temperature correction of at least 7 to 10 degree F needs to be taken into account. The flooring could be covered by wooden planks, rubber mating, and heavy carpets to minimise heat ingress. Below the chassis higher temperature exists due to tar roads getting overheated.

6) The effect of solar heat gain is more pronounced when vehicle is stationery.

7) The insulation or any other material used should be fire proof/fire resistant/fire retardant.

8) Door openings, and duration of each opening should be kept minimum.

9) The dark colours absorb heat and light colours reflect heat. Hence while selecting the bus painting, light shades to be preferred as much as possible while constructing A/C bus to reduce heat load.

AIR MANAGEMENT

SUPPLY AIR DUCTING

It should be ensured that there is no leakage in the ducts (they are perfectly sealed), or any air leaked out ends up in the air conditioned space.

The air leaving evaporator should be 20 degree F (15 to 23 range) lower than conditioned space temperature.

The temperature of air surrounding duct will be average air temperature.

When ducting air from one place to another, it is extremely important to allow air to make smooth transition from velocity (as it leaves fan) to pressure (as it moves through duct). Ducts must be smooth and obstruction free, as turbulent flow is less effective than a well balanced smooth flow and cause reduction in air quantity.

Whenever the duct is to be expanded, angle of expansion shall not be more than 7 degrees.

The area of duct connection to bus internal ducts shall be 110 % minimum of the outlet area of the unit flow.

To expand air, the minimum distance of 2.5 times the diameter is needed to allow air to move away from the fan or blower freely. For example a blower outlet of 4 inches should have 2.5 x 4 = 10 inches straight distance before transition duct is used.

In roof installations, provision must be made to assist the air to turn and make a smooth transition in to the bus ceiling ducts.

When cold ducts are located in warm humid areas of the bus, condensate will form on the duct. A thin layer of insulation on ducts will prevent this and will minimise heat gain through the duct.

The duct must be able to carry required air flow with minimum noise and absorb vibrations. Otherwise they may conduct and amplify it. The supply air duct should be designed for 1000 to 1500 feet per minute velocity (5 to 7 m/sec).

For 38 to 45 passengers air quantity should be about 3500 cum/hr or 2000 cfm at low blower speed.

The duct size for a roof top unit centrally mounted will have flow of 500 cfm. per branch leading to duct size ranging from 48 to 72 sq.in. cross sectional area based on 1500 to 1000 fpm. velocity. And for rear mounted units it should be 96 to 144 sq.in. for air flow of 100 cfm. per branch.

Any plumbing, electrical or other items mounted inside the ducts will restrict air and total flow of distribution within the bus. The area of duct therefore should be suitably increased.

While connecting the duct to evaporator, flexible connectors/ canvas connectors should be used. They help in isolating machine vibrations by keeping them from travelling from the machine into duct work. Flexible connectors must be installed so that they are not stretched out tight. On the other hand they should not be so loose as they sag and thus are likely to block the air stream.

The ducts running lengthwise inside the bus should have fixed and adjustable openings for uniform air distribution inside the bus. The recommended permanent outlets/ open area should be about 150 sq.in. (967 sq.cm.) whereas adjustable outlet area 50 sq.in. (323 sq.cm.) for 100 sq.in. (645 sq.cm.) duct size. The total area of openings is therefore 200 sq.in.(1290 sq.cm.) leading to a velocity of about 3.5 m/sec.

The total available air flow reduces as static pressure increases. With undersized ducts, the cooling capacity available may be adequate to handle the needs, but smaller duct will restrict unit's performance and internal comfort conditions will be less than desired.

Permanent openings shall be distributed evenly over the length of duct with 40% area directed in to the isle and remaining 60% to be directed near window area of bus.

Testing of typical installation is a must to achieve a uniform temperature distribution and passenger comfort.

The air flow must be balanced from front to the rear of the bus.

The air which is directed into the window areas of the bus should be directed so that the flow of air does not directly hit the windows. Best performance is achieved if the air flows out parallel to the window. This will minimise the scrubbing effect of the air, resulting in reduced heat transfer through the glass and still give moisture free windows with the minimum noise level.

When temperature inside the bus starts falling and the passengers are comfortable, the tendency of passengers is to close the adjustable air outlets. If all air outlets are closed and if the ducts are not provided with permanent openings, due to high resistance the air quantity will reduce and there is a possibility of coil freeze up. It is therefore essential to keep permanent openings which cannot be closed. Generally at the end of the longitudinal duct an opening is provided to avoid back pressure and to ensure certain minimum air flow to prevent coil freeze up.

RETURN AIR:

Generally there is no separate duct for the return air provided inside the buses. The return air is generally through grills provided. It should be ensured that there is an easy access to return air filters for cleaning. It should also offer aesthetics to coach interior when grills are provided. The grill open area should not be less than 80% of the total coil face area and should be constructed to allow the air a smooth path to the coil.

If an obtuse air path is required due to unusual locations, then plenum area large enough to minimise turbulence at the unit inlet must be used.

DUCT LINING :

The internally lined/ insulated duct although costly, will help to serve to absorb noise. The duct size in such cases needs to be suitably increased to accommodate thickness of extra insulation/ lining. Care should be taken to ensure that duct lining is firmly fixed, otherwise it would become loose and obstruct air flow.

Air movement across the surface of the bus:

The air moving along a surface tends to be pulled into that surface by friction of air. The moving air creates a negative pressure inside the opening. The faster the air moves over the opening the more negative the pressure in the opening.

The effect of opening with or without the bump in the roof may be compensated by adding an air dam or scoop. Similarly air flow through the condenser must not be allowed to recirculate back through the condenser and proper baffles should be provided to separate supply air and exhaust air paths.

GLASS AREA/ WINDOWS:

The air leakage through windows is of large magnitude if they are sliding types. Many body builders provide windows which can be half opened. This generally adds to the cooling load. The ideal construction should be to seal window glasses so that passengers cannot open them. A single glass, tinted glass or double tinted glass are the various options, with double tinted glass as most preferred option, since air trapped between two glasses serves as best insulation.

The air conditioning system should be designed in such a manner that even if cooling is stopped due to temperature reaching desired levels, the ventilation fans should be running to prevent suffocation.

In the event, the ventilation fans also stop, ventilation can still be achieved by providing extra fans located near passenger seats or providing ventilation hatches, or exhaust fans on the roof which are activated automatically when air conditioning unit with its fans stops due to malfunction. These are some of the preferred options rather than providing windows which are of openable type.

To sum up, if the body builder has the knowledge of air conditioning system and how it is going to perform efficiently if he takes proper and adequate precautions at the time of constructing air conditioned bus, the overall result will be optimum system operation. Some of the key areas he should therefore keep in mind and exercise control are :

1. Effort to be made to ensure low vibration and noise transmission.

2. Minimum heat leakage inside air conditioned area through engine hood, roof and floor.

3. Air tightness through doors and windows.

4. Adequate and proper duct design

5. Sufficient return air area.

6. No recirculation of condenser or evaporator air.

7. Ease of maintenance, particularly approach to the filters for cleaning.

It can thus be seen that only a well engineered A/C unit will not suffice to get the best from the total system and the body builders and installers have to play equally a major role to ensure that the overall system operates to the satisfaction of every one concerned.

TYPE OF SYSTEMS

1. INTEGRATED
2. REAR MOUNT
3. ROOF TOP
4. SUB ENGINE

SR. NO. 1, 2, 3 - EITHER MAIN ENGINE DRIVEN OR SEPARATE POWER PACK.

BUS AIR CONDITIONING CAPACITY OF UNIT

BUS LENGTH	NO. OF PASSENGERS	COOLING CAPACITY KCAL/HR.
UPTO 5 M.	10-15	8,000
6 TO 8 M.	22-25	14,000
10 TO 12 M.	38-45	22,000

TYPICAL BUS AIR CONDITIONING SPECIFICATIONS

NO. OF PASSENGERS	47
BUS LENGTH	10-12 M. LONG
INSULATION THICKNESS	25-38 MM
WINDOWS	SEALED, DOUBLE, TINTED
UNIT DESIGNED UPTO	50 DEGREE CENTIGRADE MAX.
SHOCK LOAD	3 TO 5 G.
FRESH AIR	670 CU. M./HR (400 CFM.)
DOOR OPENINGS	7 PER HR MAX.
DURATION NOT EXCEEDING	7 SECS. MAX.
INSIDE CONDITION	23 C MAX. DURING DAY 25 C MAX. NIGHT R. H. 55 TO 60%
TEMPERATURE GRADIENT	+/- 2 DEGREE C
PULLDOWN TIME	43.3 C TO 27 C IN 20 MINUTES UPTO 23 C IN TOTAL 30 MINUTES MAX.
AIR VELOCITY	3.8 M/SEC. AT SHOULDER LEVEL
TOTAL AIR QUANTITY	3500 CU. M. AT LOW SPEED
ESTIMATED LOAD	18 TO 35 K.W.- HIGHLY VARIABLE AS PER CONDITIONS