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Analysis of Air Conditioning System in Locomotive

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Abstract-Transportation is one of the need of human being, which is existing since the evolution of mankind. The challenge today lies identifying the most appropriate product, or mix of products, for the application at hand. Every air conditioning application has its own special ‘needs’ and provided its own challenges. So,Air-conditioning is no longer a luxury but an essential part of modern living. In this, analysis of air-conditioning is done for a locomotive. Considering ASHRAE standards, heat load calculations are performed taking into account all the sources of heat generation in locomotives. Based on the heat load calculation the air distribution system in a locomotive is designed which includes the ducting.

Index Terms-Air-conditioning, Locomotive, Transportation.

1. INTRODUCTION

In general air conditioning is defined as the simultaneous control of temperature, humidity, cleanliness and air motion.Depending upon the requirement, air conditioning is divided into the summer air conditioning and the winter air conditioning.The former uses a refrigeration system and a dehumidifier against a heat pump and a humidifier used in thelatter.

Necessity of AirConditioning:

Air conditioning and refrigeration are provided through the removal of heat. Heat can be removed through radiation, convection, and by heat pump systems through a process called the refrigerationcycle.

The refrigeration cycle uses four essential elements to create a cooling effect. The system refrigerant starts its cycle in a gaseous state. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a "condensing coil" or condenser) where it loses energy (heat) to the outside. In the process the refrigerant condenses into a liquid. The liquid refrigerant is returned indoors to another heat exchanger ("evaporating coil" or evaporator). A metering device allows the liquid to flow in at a low pressure at the proper rate. As the liquid refrigerant evaporates it absorbs energy (heat) from the inside air, returns to the compressor, and repeats the cycle. In the process heat is absorbed from indoors and transferred outdoors, resulting in cooling of thebuilding.

Heat Getting Inside Avehicle:

When a car is driven or parked in the sun, heat enters the vehicle from many sources. These sources include:

- Ambientair
- Sunlight
- Engine heat
- Road heat
- Transmission
- Exhaustheat

All of these and other miscellaneous heat sources, increase the air temperature within the vehicle. In a high ambient temperature situation, (e.g. on a 37°C day), the interior of a vehicle left standing in the sun with windows closed could reach 65°C - 70°C.

To understand just how an air conditioning system works, we must first understand the nature of heat. All substances contain heat. Something "feels" hot when it is warmer than our body temperature. When something contains less heat than our bodies, we say it feels cold! Cold is merely the removal of some heat. Heat in the correct amount will provide life and comfort. Heat in either extreme - extreme to much or too little - will be uncomfortable. The control of temperature means the control of comfort. Air conditioning is a method of controlling heat.

2. HEATTRANSFER

Heat transfer is the process of transfer of heat from high temperature reservoir to low temperature reservoir. In terms of the thermodynamic system, heat transfer is the movement of heat across the boundary of the system due to temperature difference between the system and the surrounding.

There are 3 modes of heat transfer:

i. Conduction
ii. Convection
iii. Radiation

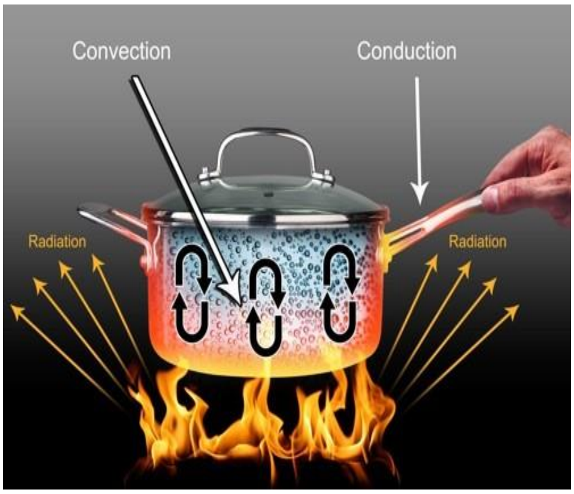

Fig1: Modes of Heat Transfer

Compressors:

There are various makes and types of compressors used in automotive air conditioning systems operating on R134a.The internal design could be Piston, Scroll, Wobble plate, Variable stroke or Vane. Regardless, all operate as the pump in the A/C system to keep the R134a and lubricating oil circulating, and to increase the refrigerant pressure and thus temperature.

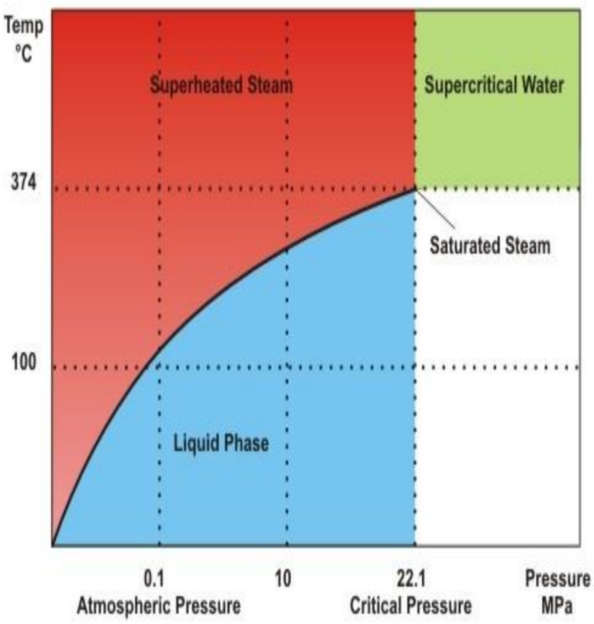

Fig2: Distribution of Pressure and Temperature of Various Types of Steam

Wiring A/C System: Control/Wiring layout

(SeriesConnection):

Pressure switches are connected in series with the compressor clutch. If an "under" or "over" system pressure occurs the pressure switch will "open circuit" breaking the circuit to the compressor clutch.

With electronic fuel injected vehicles, the Electronic Control Module (ECM) is usually interconnected into the A/C wiring circuit. When the A/C switch is engaged, a request signal is sent to the ECM, if the A/C circuit is intact, i.e. the pressure switches are a closed circuit, the ECM activates a relay by creating an earth and power is supplied to the compressor clutch. Also, an RPM increase generally takes place to avoid engine stall whilst atidle.

3. BUS AIR CONDITIONING DESIGN

Cooling Loadfactors:

Occupancy:

Occupancy per unit volume is high in automotive applications. The air conditioner must be matched to the intended vehicle occupancy.

***Infiltration*:**

Like buildings, buses are not completely sealed: wiring harnesses, fasteners, and many other items must penetrate the cabin. Infiltration varies with relative wind/vehicle velocity. Unlike buildings, buses are intended to create a relative wind speed, and engines may emit gases other than air. Body sealing and body relief vents are part of air-conditioning design for bus. Occasionally, sealing beyond that required for dust, noise, and draft control isrequired.

By design, vehicles are allowed to have controlled body leakage that allows air movement in the vehicle to provide comfort to the passengers. This also helps control moisture build-up and the occupants perceived comfort level. However, excessive body leakage results in loss of heating and cooling performance. Vehicle body leakage characteristics typically are significantly different in dynamic conditions in comparison to the static conditions. According to SAE standard J638, infiltration of untreated air into the passenger compartment through all controlled and uncontrolled exit points should not exceed 0.165 m/s at a cabin pressure of 0.25kPa. However, each vehicle has different body leakage characteristics. Some vehicles have two drafters in-side the trunk on either side, and some have only one.

***Insulation*:**

Because of cost and mass considerations, insulation is seldom added to reduce thermal load; insulation for sound control is generally considered adequate. Additional dashboard and floor thermal insulation helps reduce cooling load. Some new vehicles have insulated HVAC ducts to reduce heat gain during cooling and heat loss during heatingmode.

Thermal Comfort and Indoor AirQuality:

ASHRAE standard 55 provides information on the airflow velocities and humidity required to provide thermal comfort. Effective comfort cooling system design in cars must create airmovement in the vehicle, to remove heat and occupants body effluents and to control moisture build-up. Assuring an effective temperature of 22 degrees centigrade with no solar load at 24^o C, 98% of people are comfortable with zero air velocity of 2.5 m/s. If panel vent outlets can deliver sufficient air velocity to the occupants, comfort can be reached at a higher in- vehicle temperature than with lowairflow.

Relative Humidity:

Also affects cabin IAQ. Too high a level affects occupants comfort and can lead to condensation and fogging on windows. A relative humidity sensor can detect excessive humidity and intervene.

Ambient Temperatures and Humidity:

Several ambient temperatures need to be considered. Heaters are evaluated for performance at temperatures from -40 to 21 degrees centigrade. Air-conditioning systems are evaluated from 4 to 45 degrees centigrade, although ambient temperatures above 52 degrees centigrade are occasionally encountered. The load on the air-conditioning system is also a function of ambient humidity. Typical design points follow the combinations of ambient temperature and humidities of higher probability, starting at round 90% rh at 32 degrees centigrade and with decreasing humidity as temperature increases.

Because the system is an integral part of the vehicle, the effects of vehicle-generated local heating must be considered. For interior components, the design high temperature is usually encountered during unoccupied times when the vehicle is soaked in the sun. Interior temperatures as high as 90 degrees centigrade are regularly recorded after soaks in the desert southwestern United States.

Power Consumption andAvailability:

Many aspects of vehicle performance have a significant effect on vehicular HVAC systems. Modern vehicles have a huge variety of electric-powered systems. The need to power these systems while maintaining fuel efficiency leads manufactures to demand a high level of efficiency in electrical power usage. On some vehicles, electrical power use is monitored and reduced during times of minimal availability. The mass of the HVAC system is also closely controlled to maintain fuel efficiency and for ride or handling characteristics. Automotive compressors must provide the required cooling while compressor speed varies with the vehicle **condition** rather than the load requirements. Vehicle engine speeds can vary from 8.3 to 100rev/s.

***Classification of Bus AirConditioning*:**

In general, bus air-conditioning systems can be classified as inter-urban, urban, or small/shuttle bus systems. Bus air-conditioning design differs from other air-conditioning applications because of climatic conditions in which the bus operates, equipment size limitations, and compressor rev/s. Providing a comfortable climate inside a bus passenger compartment is difficult because the occupancy rate per unit of surface and volume is high, glazed area is very large, and outside conditions are highly variable. Factors such as high ambient temperatures, dust, rain, snow, road shocks, hail, and sleet should be considered in the design. Units should operate satisfactorily in ambient conditions from -30^o C to 50^o C.

Ambient air quality must also be considered Vehicle motion also introduces pressure variables that affect condenser fan performance. In addition, engine speed governs compressor speed, which affects compressor capacity. R-134 is the current refrigerant of choice, but some units operate with refrigerants such as R-22 orR-407C.

Reliability and ease of maintenance are also important design considerations. All parts requiring service or regular maintenance should be readily accessible and repairs should be achievable within a minimum time.

HeatLoad:

The main parameters that must be considered in bus air-conditioning system design include:

- Occupancydata
- Dimensions and optical properties ofglass
- Outside weatherconditions

The heating or cooling load in a passenger bus may be estimated by summing the heat flux from the following loads:

- Solid walls(side panels, roof, floor)
- Glass(Slide, front and rearwindows)

- Passengers

Extreme loads for both summer and winter should be calculated. The cooling load is the most difficult load to handle; the heating load is normally handled by heat recovered from the engine. An exception is that an idling engine provides marginal heat in very coldclimates.

The following conditions can be assumed for calculating the summer heat load in an interurban vehicle similar to that.

- Capacity of 50Passengers
- Insulation thickness of 25 to 40mm
- Double-pane tintedwindows
- Outdoor air intake of 190L/s
- Road speed 100km/h

Loads from 12 to 35 kW are calculated, depending on outside weather conditions and geographic location.

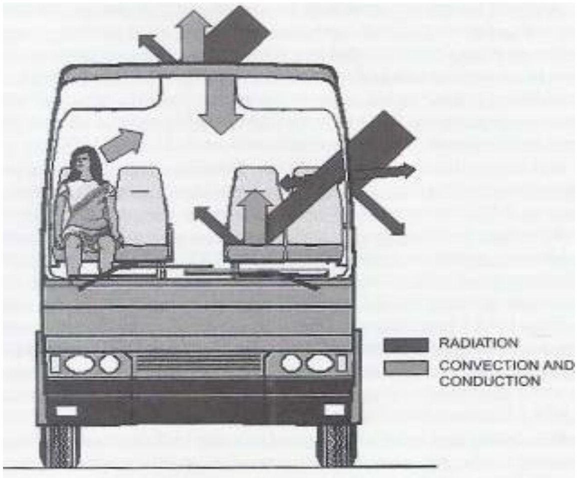

Fig3: Heat Transfer processes in BUS

The Typical distribution of the different heat loads during a summer day at 40 degrees north latitude.

HeatLoad:

∑ R =Ri + X1 R1 + X2R2 +..................................... n Rn +R0

Ri = Resistance of inside

ASHRAE = American Society of Heating Refrigeration & Air Conditioning Engineers

Solar heat gain through glass

Specification of Glass: It is a shaded glass which is dark on outer side and lighter on inner side vertical glass.

Directions are not considered as it's a bus which is usually mobile the factor of absorption of heat is 3.725

Solar & transmission heat gain through wall & roof

Specification of wall: The material used for the entire body inclusive of walls is metallic body with an insulation on the inner side which exhibit an absorption coefficient2.751

The solar transmission through the walls is zero as the vehicle is mobile and thus not considered

Roof = A x ⌂T x U

Specification of roof: the material of the roof is the same as that of the wall

= 30x30.525x0.917

=831 watts

Transmission Heat gain through glass:

Specification of a glass:

It is a shaded glass which is dark on outer side and lighter on inner side vertical glass.

Directions are not considered as it's a bus which is usually mobile the factor of absorption of heat is 0.65

All glass = 59.46 x 17.3 x 3.725 = 3832watts

Partition:

Specification: The partitions are not as the area is bus which doesn't have any partitions

Infiltration or outside Air quantity:

Infiltration = cmh x ⌂T x 1.08

= 394 x 17 x 0.33

=2250 watts

Outside Air = cfm x ⌂T x BF x 0.33

BF - By pass factor

Contact factor + BF = 1

CF = 1- BF = 0.8

Constant=0.33

InternalHeat:

People = no.of people x sensible heat gain / person

= 36 x67= 2426

Lights = W /sqft x Area x 3.41

= 6.46 x 29.7 = 192

Appliances = 29.7 x 26.94 = 800

Room sensible heat = 13889 watts

Factory of safety (14%) = 1389 w

Effective room sensible heat (Qs) = 15277 w

Latent heat:

Infiltration = cmh x ⌂gr x BF x 0.8

= 394 x 3.15 x 0.2 x 0.8

= 1624w.

Outside air = cmh x ⌂gr x BF x 0.8

= 1835 x 5.15x 0.2 x 0.8

= 1512w

People = no. of people x latent heat gain / person

= 36 x 35 =1260 w

Room latent heat

= infiltration + outside air + people

= 4396 w

Factory ofsafety 5%= 220 w
Effective room latent heat (Ql) = 4616 w
Eff room total heat (Qt) = Qs + Ql
= 15277 + 4616

= 19893 w

Outside air heat:

Sensible = cmh x ⌂T x CF x 0.33

= 1835 x 17 x 0.8 x 0.33

= 8381 w
Latent = cmh x ⌂gr x CF x 0.8

= 1835 x 5.15 x 0.8 x 0.8

= 6048 w

Grand subtotal heat = Qt + S.H + L.H

= 14428 w
Factory of safety (2%) = 1030 w
Grand total heat = 35351

1TR-------------------------------------- 3517 w

Therefore = 35351 / 517 = 10.05 TR
Effective sensible Heat factor (ESHF) = Qs / Qt = 58846 /5120.96 = 0.93
Apparatuses due temperature:

ESHF	0.74	0.75	0.76	0.77	0.78
ADP	48	48.5	49	49.5	50

ADP = 49.5^{o}F = 9.7^{o}C
Dehumidified Rise = (1-BF) x (Rm Temp - ADP)
= (1-0.2) x (75 – 49.5)
= 11.26 ° C

Dehumidification CFM = Qs / 0.33 x DR

= 15277/ 0.33 x 11.26
= 4110 CMH

Air Distribution:

Air-conditioning units are configured to deliver air through ducts to outlets above the windows or to act as free-blow units. In the case of free-blow units, louvers guide the air distribution inside the bus.

InterurbanBuses:

These buses are designed to accommodate up to 56 passengers. The air-conditioning system is usually designed to handle extreme conditions. A four- or six-cylinder reciprocating compressor, in which some cylinders are equipped with un-loaders, is popular. Some interurban buses have a separate engine-driven compressor, preferably scroll, to give more constant systemperformance.

***UrbanBuses*:**

Urban bus heating and cooling loads are greater than those of the interurban bus. A city bus may seat up to 50 passengers. The fresh air load is greater because of the number of door

Openings and the infiltration around doors. Cooling capacity required for a typical 50-seat urban bus is from 20 to 35 kW. The buses are usually equipped with a roof- or rear-mounted unit. Therefore, capacity control must compensate for not only the thermal load but also the engine-induced load. Cylinder un-loaders are the primary means of capacity control, although evaporator pressure regulators have been used with non-unloading compressors.

Small or ShuttleBuses:

For small or shuttle buses such as those operating around airports or for schools, the evaporator is usually mounted in the rear and the condenser on the side or the roof of the bus. The evaporator unit is typically a free-blow unit.

RefrigerantPiping:

All components in the bus air-conditioning system are interconnected by copper tubing or refrigerant hose. When using copper tubing, care should be taken to analyze the effect of vibration on the tubing. Vibration effects can be minimized by using vibration absorbers or other shock- cushioning devices.

SystemSafety:

Per the U.S. Department of Transportation, all buses with air-conditioning systems operating in North America should conform to Federal Motor Vehicle Safety Standard (FMVSS) 302 for flammability standards. In addition, all evaporator units inside the vehicle should be mounted away from the head impact zone, as specified by FMVSS222.

Controls:
Most buses have a simple driver control to select air conditioning or heating. In both modes, a thermal sensing element controls these systems use solid-state control modules to interpret the bus interior and outside ambient temperatures and to generate signals to operate full or partial cooling or heating functions. In these systems, thermistor temperature sensors are used, which are usually more stable and reliable than electromechanical control.

4. FUTURE SCOPE

The Future of Automobile Air Conditioning:

Air conditioning system finds its use in various fields of our life. In case bus there has been a significant demand in the commercial trucks and buses including urban transport.

1. UrbanBuses:

The Government of India has implemented city bus made by Volvo and Tata motors have in recent years installed with air conditioning system in various cities throughout India. This includes Volvo 8400 citybus.

2. Commercialtrucks:

Commercial trucks producing companies such as AMW, Mahindra & Mahindra, Ashok Leyland and Tata Motors have introduced air-conditioned cabins in Tipper, haulage as well tractor trailer. Most of these cabins are found in the Tipper as these mostly work in mines and the working conditions are very uncomfortable.

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