Implementation Of New A/C System In Air-Plane Cabin

Jasem Mohammed Abdeen

Abstract: There are three situations used to provide cooling air for both flight deck equipment and the main equipment centre compartment racks in the aircraft, the first one is in flight operations: Since the bleed of air supply is always at higher temperature than what is required for the passenger comfort, a means of cooling this air is accomplished in flight by a simple air-to-air heat exchanger; this heat exchanger uses ambient ram air as a heat sink. (to reduce the heat). The second one during ground services: When an air plane is at ground being prepared for the next flight, a moveable air-conditioning system servicing from under the fuselage centre section to meet user system demands. And the third one when the ground services complete, the moveable air conditioning system will be disconnected and then the airplane will be moved to the run way for the departure. This means that it is a critical duration of time because there is no air conditioning is provided to the seating area of the passengers and the temperature of the area will raise to about (90°F) and 85% humidity. It is more critical if this duration of time will be longer which means a higher temperature will be, and leads to passengers discomfort as the pilot will not be able to provide any A/C to the passenger till the airplane is in flight operation.So this paper provides a full study and analysis that leads to develop a new air conditioning system for Aircraft (A320), which can be operated while the aircraft is at the gate or during the critical time between the end of ground service and take off. The successful development of the concept could create a new industry within the Middle East. To achieve the aim of this study, A\C load determination, Air craft structure, zones, existing A\C system description, ventilation system and pressurization system are needed to make a full study on the required design condition.

1. INTRODUCTION

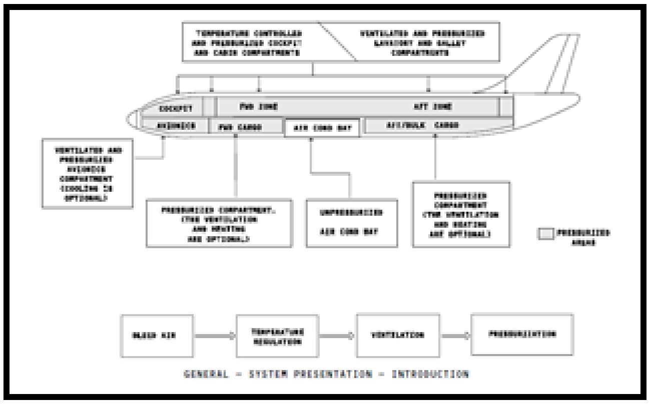
This study aims to describe a new design that leads to develop a new air conditioning system for aircraft (A320), which can be operated while the aircraft is at the gate for ground service. The study consists of two parts. The first part consists of a theoretical part that gives a full description of existing air conditioning in aircrafts and compared it to refrigeration planets found in industry. The second part consist of design part where a full design drawings are done to solve the problem. The purpose of this of this work is to provide a full study that leads to implement a new air conditioning system, while they are at the gate in hot and humid conditions. The proposed design must to ensure the passenger safety and comfort throughout the phases of the aircraft at ground.

Air-condition in A-320 Aircraft

Modern transport aircraft operate in a wide variety of environmental conditions. These can be from (-56°C) or below at high altitude to temperatures in excess of (+56°C) in tropical locations. There are strict regulations for the minimum requirements of conditioned air for the passengers and crew of aircraft. These do not only cover the temperature but also the oxygen content, ventilation, humidity, quantity and pressure.

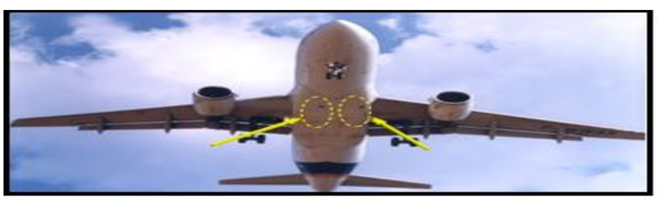
Figure(2-1): auxiliary power unit (APU)

Commercial aircraft operate in a physical environment that is not survivable by unprotected humans. This requires a complex environmental control system (ECS) to provide passengers and crew with safety and comfort without health risks. But while the aircraft is at the gate. Environmental control system (ECS) can be powered by bleed air supplied by the auxiliary power unit (APU), bleed air from a ground cart, or bleed air from the main engine start. see figure (2-1). The (APU) or ground –cart bleed air is ducted directly to the bleed air manifold upstream of the air conditioning packs.Moving the aircraft from the gate, the aircraft engines are at low thrust, pushing the aircraft slowly along the runway. In the cold countries the hot air readily available from the main engine compressor, is tapped off mixed with cold outside air and supplied to the cabin with required comfortable temperature. In typical system the aircraft pneumatic manifold supplies hot air to two separate and independent cooling packs located in the fuselage (aircraft main body) under the center wing section.(Air cooling pack system is explained in section 2.4). The cooling packs are controlled by electro pneumatic pack valves. The pack valves are opened or closed by switches on the pilot's over head panel. Each cooling pack supplies cold air to the main distribution manifold. Before entering the main distribution manifold, the hot and cold air is mixed together .The ratio of hot to cold air is determined by the temperature control system.In hot countries a bleed air from the main engine can not be mixed with a (50°C) outside air temperature , as the final temperature of the mixing ratio does not reach the required comfortable cabin air temperature which should be with the range (22°C) to (27°C).Therefore the primary objective of this work is to provide a full study that leads to implement a new air conditioning system for these modern aircrafts, while they are at the gate in hot and humid conditions.The proposed system must be designed to ensure the passenger safety and comfort throughout the phases of the aircraft at ground. Prior to start putting our idea to the most suitable A/C system to be used , it is essential to brief study on the requirements of the air conditioning system and the typical air conditioning system used in aircraft. During our survey study on many aircraft types and through a lot of meeting which held with many airways personal in the gulf states , we found that their main problem come with the aircraft carrier airbus A320. the technical staff are seriously thinking to use any commercial HVAC system to provide pretreated cooled air to the aircraft during its stay at the gate to overcome many serious complains by the passenger. Many discussions were held with airways representative and decided to concentrate our main study on this aircraft type. To apply the proper air conditioning system which maintains the air in the pressurized fuselage zone at correct level of temperature freshness and pressure , we must give a full study of existing air conditioning system to ensure the compatibility of proposed system with the existing system. A simply layout Figure (2-2) of A320 aircraft shows the aircraft zones and system presentation.

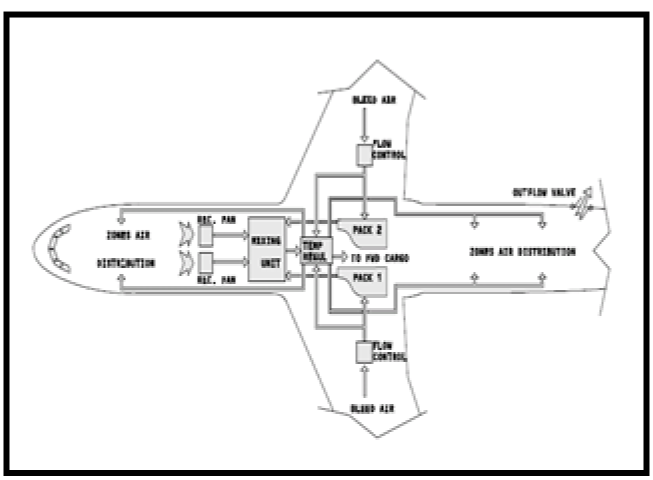


Figure(2-2): Air craft system Presentation

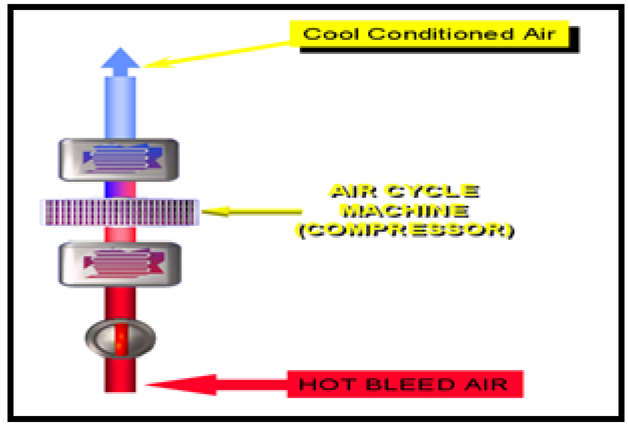
Like the majority of the systems in A320 the air conditioning is fully automatic we will begin our study of the system by looking in to the conditioning packs.The A320 is equipped with two air conditioning packs located in the wing root area forwarded of landing gear bay figure(2-3) , figure(2-4) .



Figure(2-3): two air conditioning packs located in the wing root

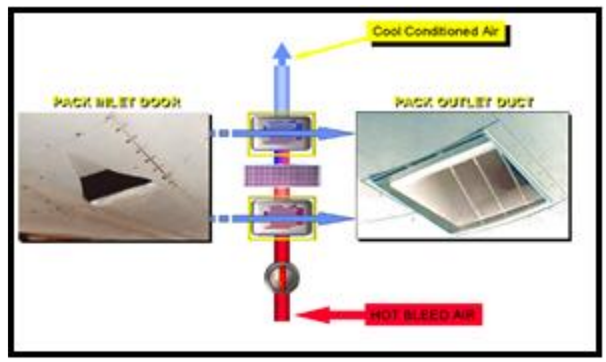


Figure(2-4) : two air conditioning packs located in the wing root area forwarded of landing gear bay



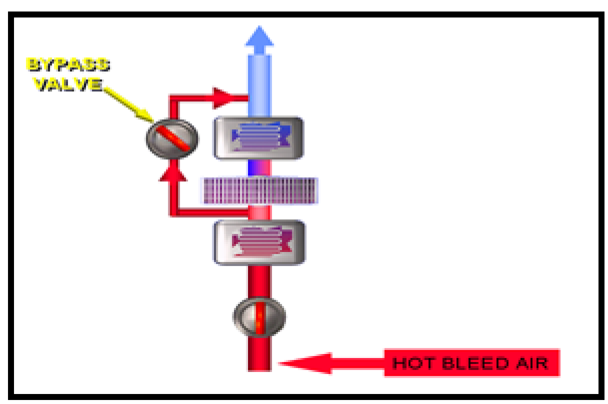
Figure(2-5): Air cycle in the pack

The air then passes through serveral stages within the pack Figure(2-5) that progressively cool the air to provide a conditioned air output.



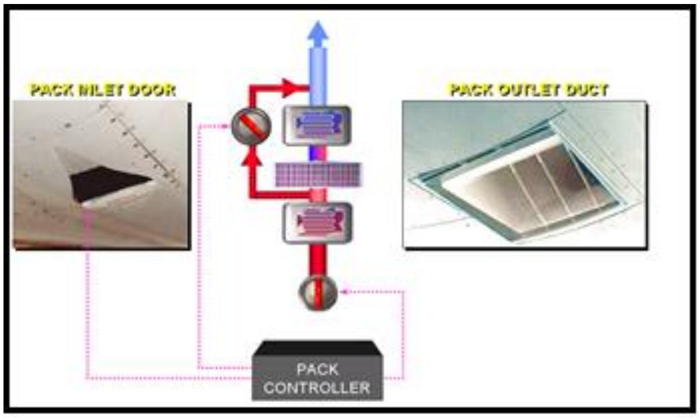
Figure(2-6): Heat exchange mixer

Two of the stages are heat exchangers that use flow of ram air to cool the bleed air Figure(2-6). This flow air enters via a pack inlet door and exist via an outlet duct .



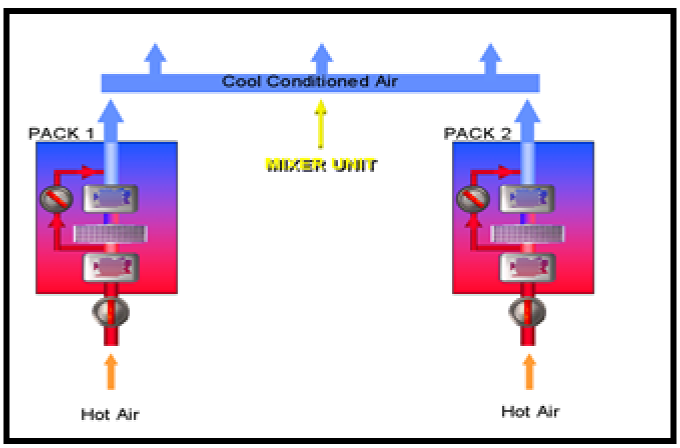
Figure(2-7): By pass valve from flow warm air

The out put temperature of the pack can be adjusted through a bypass valve which allow warmer air to be mixed with the cold air Figure(2-7).



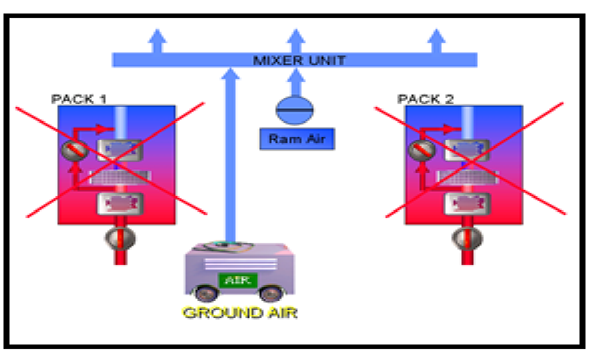
Figure(2-8): By pass valve from flow warm air with pack controller

The pack flow control valve , the bypass valve and the inlet door are regulated by a pack controller to vary the amount of the air passing over the heat exchanger Figure(2-8).



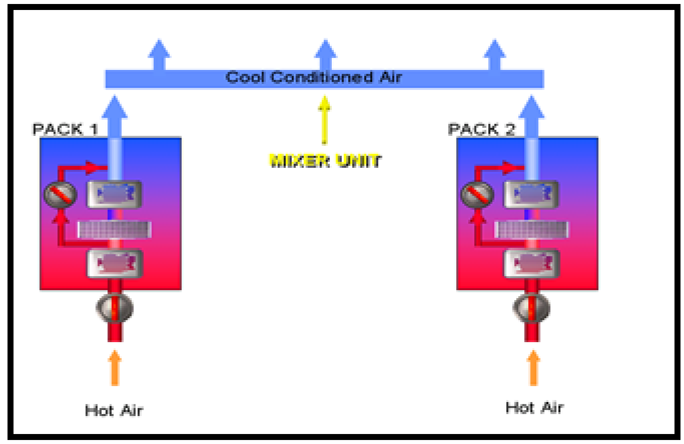
Figure(2-9): Two air conditioning packs

The two air conditioning packs operate automatically and independently and feed air to a mixer unit Figure(2-9).



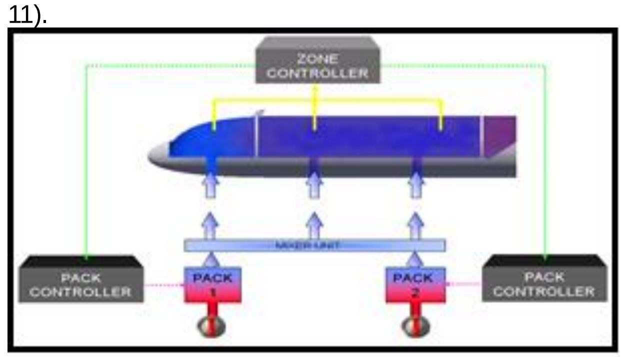
Figure(2-10): The connection between ground air(APU)

The mixer unit mixes air from packs and re-circulated air from the cabin prior to distribution to each zone. See Figure(2-10).



Figure(2-11): Two air conditioning packs

The mixer unit installed under the cabin floor uses cabin air which has entered the under floor area and has been drawn through recirculation fans. This air is mixed with conditioned air from the packs. The quantity of cabin air mixed with conditioned air varies from 37% to 51%. The mixer unit may also receive conditioned air from a low pressure ground connection (APU) or ,in flight fresh outside air from emergency ram air flap .Figure(2-11).



Figure(2-12): Zone controller that control

Various pack parameters pack, flow, outlet temperature, by pass valve position and pack out let temperature are monitored by ECAM. These parameters are shown clearly in Figure(2-14) The conditioned air is distributed to three main zones, cockpit, forward cabin and aft cabin. (Refer to figure 2-2). A zone controller monitors the temperatures of the three zones and sends signals to the pack controllers to set the air temperature delivered by the packs Figure (2-12).

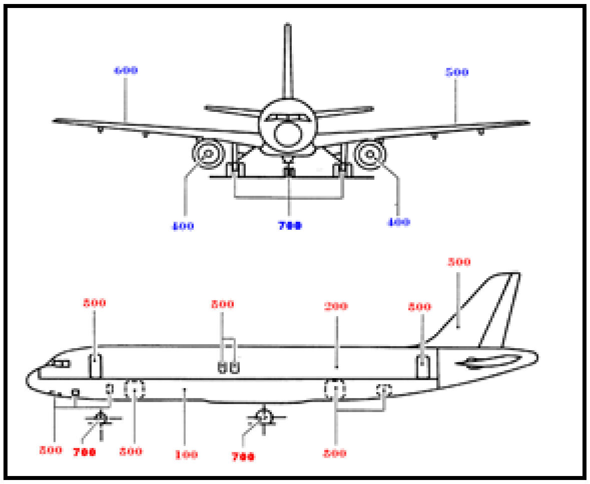


Figure (4-1): Major zones

Aircraft body structures survey

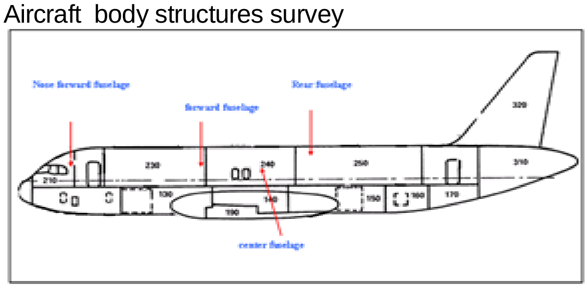


Figure (4-2): Aircraft major sub-zones

The primary function of air conditioning is to maintain conditions that are conductive to human comfort ,or required by process within the space. To perform this function, equipment of the proper capacity must be installed and controlled throughout the running time. The equipment capacity is determined by the actual instantaneous peak load requirements. Before the load can be estimated, it is imperative that a comprehensive survey be made to assure accurate evaluation of the load components. If the aircraft facilities and the actual instantaneous load within a given mass of the aircraft are carefully studied, an economical equipment selection and system design can result, and smooth, trouble free performance is then possible.

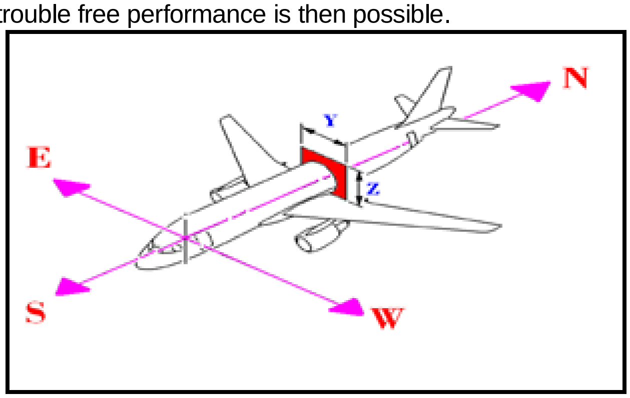


Figure (4-3): Aircraft orientation

Space characteristics and heat load sources:
An accurate survey of the load components of the space to be air:-
Conditioned is a basic requirement for a realistic estimate of cooling and heating loads. The completeness and accuracy of this survey is the very foundation of the estimate, and its importance can not be overemphasized. Mechanical and architectural drawings, complete field sketches and in this case, photographs of important aspects are part of a good survey.
The following physical aspects are considered.

* Orientation of aircraft
* Use of space
* Physical dimension of aircraft
* Construction material
* Windows
* People:
* Lighting:
* Appliances

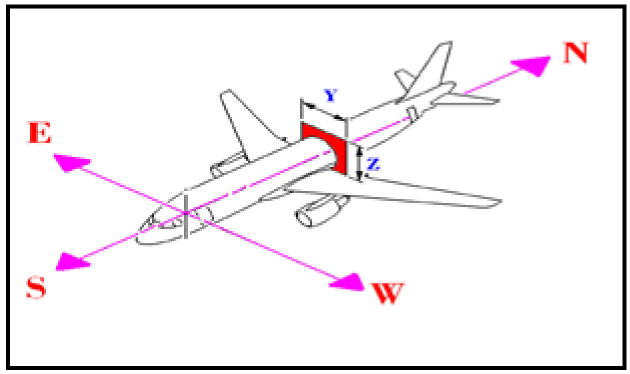


Figure (4-3): Aircraft orientation

The above aspects are thoroughly discussed in full details .
3.3 Design conditions:

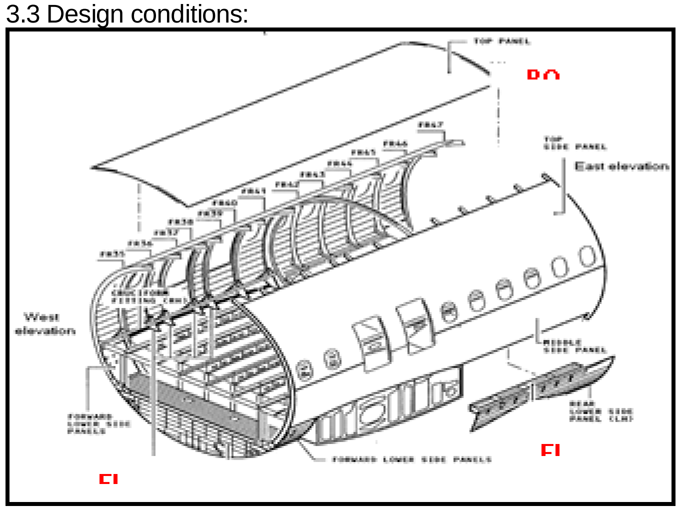


Figure (4-4): Center Fuselage – Frame and skin panel location

climatic conditions:
The heat load estimated for the aircraft is based on Kuwait conditions. The climate is severe in summer, between may and September very high ambient temperatures are experienced. The ambient temperature in the summer months reaches just above (50°c) in the shade. From October to April temperatures are generally moderate but extreme temperature of (-3°c) have been recorded. Rainfall is sparse but the intensity of the precipitation may be considerable.

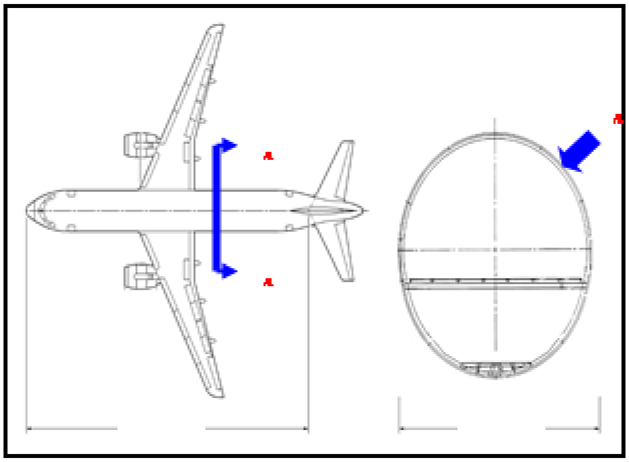


Figure (4-5): Width and Datum length of air craft

Storms during which (25mm) of rainfall in one hour have been recorded. The prevailing winds are forming the North West with secondary winds from the south east. Velocities are usually below 6-7 meters per second (13.4 to 15.6 m.p.h) and winds of over 15 meters per second (75 m.p.h) have been recorded. Relative humidity of (100%) have been registered at a temperature of (29.4°c) 85° F. Fin dust is always found in the atmosphere and sand storms occur.

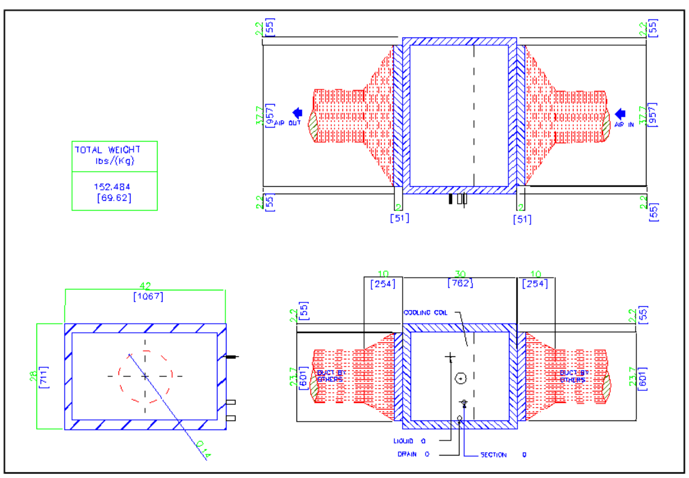


Figure (4-7) : A full design detail drawing of the evaporator unit

design conditions

Design conditions are generally based on Kuwait condition:

outside design condition

summer 115 FDB/82FWB

winter 40 FDB/ 35.6FWB

Daily range 24° F

Indoor design Conditions

summer 70° F /50% RH

winter 71.6° F / 50% RH

Calculation and Results

4.1 Calculating Heat Load

The amount of heat generated is known as the heat gain or heat load. Heat is measured in either British Thermal Units (BTU) or Kilowatts (KW). 1KW is equivalent to 3412BTUs.

The heat load depends on a number of factors, by taking into account those that apply in your circumstances and adding them together a reasonably accurate measure of the total heat can be calculated.

Factors include:

The floor area of the air plane.

The size and position of windows, and whether they have blinds or shades .

The heat generated by equipment.

The heat generated by lighting .

Number of occupants.

A accurate load calculations are an important part of the design process .This importance is underscored by the constant evolution of load calculation methodologies which has steadily made load calculations more complex, less intuitive, and more dependent upon computers.

Today, detailed cooling load calculations are often done with the aid of computer programs because of the many inter Active and varying factors.

So I use Carrier's Hourly Analysis Program (HAP) that provides versatile features for designing HVAC systems . It also offers powerful energy analysis capabilities for comparing energy consumption and operating costs of design alternatives.

HAP is designed for the practicing engineer, to facilitate the efficient day-to-day work of estimating loads, designing systems and evaluating energy performance. Input data and results from system design calculations can be used directly in energy studies.

4.1.1 Load estimate using hourly analysis program:

Carrier hourly analysis program (HAP) software is used for estimates design cooling loads for the airplane. Inner space (HAP) is a computer tool which assists engineers in designing (HVAC) system for buildings, and tool for estimating loads and designing systems. HAP uses the ASHRAE endorsed transfer function method for load calculation .

4.1.2 Defining the aircraft areas and location

Aircraft is divided in to different zones as shown in figure(4-1).

100 lower half of the fuselage to aft pressure bulkhead.

200 upper half of the fuselage to aft pressure bulkhead.

300 stabilizers.

400 nacelles.

500 left wing.

600 right wing.

700 landing gear.

800 doors

The objective is to calculate the required cooling load only for upper part of the airplane figure (4-2), which know as the upper half of fuselage to AFT pressure bulkhead.

The sizing calculations will only be performed for the parts indicated with the following numbers:

210 upper part of nose forward fuselage.

230 upper part of forward fuselage.

240 upper part of center fuselage.

(250-280) upper part of rear fuselag

Weather data

ASHRAE design weather conditions for Kuwait international airport will be used for this analysis. These design parameters are shown in section (3.3) in chapter (3) .

Orientation of the aircraft is based on the aircraft sitting on the ground with its direction as shown in figure (4-3).

Wall details outside surface color	light
Outside surface color absorptivity	0.45
Overall u-value	0.109 Btu/hr ft F°

Table (1)

Layers	Thickness inch	Density lb/ft2	Specific heat BTU/lbf	R-value hr ft F°	Weigh lb/ ft^2
Inside surface resistance	0.00	0.00	0.00	0.685	0.00
½ in honeycomb	0.50	45.0	0.32	0.320	1.9
Air space	4.00	0.00	0.00	0.9100	0.00
Insulation board	1.00	0.40	0.22	6.944	0.20
Aluminum plate	0.047	489	0.12	0.00011	1.40
Outside surface resistance	0.00	0.00	0.00	0.333	0.00
Total	5.547			9.19	4
Overall U- value = 0.109 Btu/hrft3f°					

Table (2)

Space data

Before design calculation can be performed, we must define aircraft layout including wall , roof , window door and floor areas, exposure orientations and external shading features.

The basic aircraft structure is divided in to nine panels figure (4-4).Walls ,roof , floor, areas.

Walls and roofs U-values

One common wall construction is used for all exterior walls and roofs ,The wall construction whose data is shown in table (1).It consist of (0.047 inch) (1.2 mm) thick Aluminum plate, 1 inch thick (25.4 mm) glass wool blanket , 4 inch thickness air space and 0.274 inch (6.95 mm) synthetic honeycomb finish.

Walls roof and floor areas

From figure (4-5) the width of the airplane (3950 mm) and the Datum length (31115 mm).

Glazing	Glass type	Transmissivity	Reflectivity	Absorptivity
Outer glazing	1/4" gray tint	0.792	0.079	0.129
Glazing 2	1/8" clear	0.841	0.078	0.081
	1/4" air space			

Roof Area = (d x π x (α/360)) x Datum length

= (3.95 x π x (60/360)) x 31.115

= 64.35 m^2

= 211.07 ft^2

East wall elevation Area

= segment of E.wall x Datum length

= (3.95 x π x (60/360)) x 31.115

= 64.35 m^2

= 211.07 ft^2

West wall elevation area

= (3.95 x π x (60/360)) x 31.115

= 64.35 m^2

= 211.07 ft^2

Floor Area = Diameter x Datum length

= 3.95 x 31.115

= 122.9 m^2

= 403.12 ft^2

Windows U-factor

Two types of window units are used for all windows in the aircraft as discussed in section (3.10) in chapter(3) .the different types size and location of the windows are :

Cockpit :

Height = 0.63m = 2 ft

Glazing	Glass type	Transmissivity	Reflectivity	Absorptivity
Outer glazing	1/4" gray tint	0.479	0.062	0.459
Glazing 2	1/8" clear	0.841	0.078	0.081
	1/4" air space			

Width = 3.94 m = 12.92 ft

Area = 25.84 ft^2

U- value = 0.565 Btu/ hr ft^2 f°

Overall shade coefficient = 0.593

Cabin windows

Height = 0.385 m

= 1.26 ft

Width = 0.292 m

= 0.96 ft

Number of windows in east elevation = 39

Total windows Area = 1.26 x 0.96 x 39

= 47.17 ft2

U-value = 0.565 Btu/hr ft2 f°

Overall shade coefficient = 0.846

Lighting

There are many type of lighting system inside the aircraft. This Type of light is discussed in section (3.9) in chapter (3).

Cockpit light

The light in cockpit are considered as Recessed unvented light ,and the total consumption power is calculated as follow:

4 numbers x 4.8 watt = 19.2 watt

2 numbers x 11.5 watt = 310.5 watt
Total power consumption of light in cockpit
Total = 329.7 watt
Passenger cabin – gally area
Recessed unvented fluorescent tubes
= 46 x 30 = 1380 watt
= 44 x 15 = 660 watt
Total = 2040 watt

Passenger reading lights

They are high intersity lights each of 6 watts 50 % diversity factor is taken
130 numbers x 6 =780 watt
Adversity factor of 50% is taken i.e total consumption power = 780 x 0.5
= 390 watt

Occupants

The maximum number of occupants is 130 passengers and 10 crews. A seated at rest activity level will be used (230 Btu/ hr person) sensible and (120 Btu/ hr person) latent
.

Floor

One common Floor construction is used. the floor u- value is (0.360 Btu/hr ft2 F̊) and data is shown in table (3)

4.2 A320 Aircraft load Calculation Using Carrier Hourly Analysis Program Version 4.1

Hourly Analysis Program (HAP) provides two tools in one package: sizing commercial HVAC systems and simulating hourly building energy performance to derive annual energy use and energy costs. Input data and results from system design calculations canbe used directly in energy studies. HAP is designed for the practicing engineer, to facilitate the efficient

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	82.3	3837	3837	Aug 1500	4.4	403.0	9.52

Zone Terminal Sizing Data

No Zone Terminal Sizing Data required for this system.

Space Loads and Airflows

Zone Name / Space Name	Mult.	Cooling Sensible (MBH)	Time of Load	Air Flow (CFM)	Heating Load (MBH)	Floor Area (ft²)	Space CFM/ft²

$$\frac{1}{U}=\frac{R}{f_i}+\frac{L}{K}+\frac{I}{f_0}$$

Where :

U = The overall conductance factor in Btu\hr ft^2 °F

f_i = The conductance factor of the inside surface film in Btu\hr ft^2 °F

$\frac{L}{K}$ = Resistance to heat flow offered by metal of tubes and fins.

f_0 = The conductance factor of the outside surface film in Btu\hr ft^2 °F.

R =Ratio of outside surface to inside surface.

The logarithmic mean temperature difference ΔT is calculated by the following equation :

$$\Delta T=\frac{(T_e-T_r)+(T_L+T_r)}{2}$$

Where :

ΔT = The arithmetic mean temperature.

T_e = The temperature of the air entering the coil.

T_L = The temperature of the air leaving the coil.

T_r = The temperature of the refrigerant in the tubes.

day-to-day work of estimating loads, designing systems and evaluating energy performance. Tabular and graphical output reportsprovide both summaries of and detailed information about building, system and equipment performance. HAP is suitable for a wide range of new design and retrofit applications. It provides extensive features for configuring and controlling air-side HVAC systems and terminal equipment. Part-load performance models are provided for split DX units, packaged DX units, heat pumps, chillers and cooling towers. Hydronic loops can be simulated with primary-only and primary/secondary configurations, using constant speed or variable speed pumps. I use the data in section 4.1.2 to 4.1.4 as input data in carrier hourly analysis program, (the load calculation sheet showing full details of the Air system for A320 aircraft attached in appendix), the out put data is shown below:

4.2.1 Air System Sizing Summary for A 320 AIRCRAFT

Air System Information

After we get the result from the Carrier Hourly Analysis Program (HAP) , we can know design our air-conditioning system .

4.3 Final Design

After we finished, we get a copy of calculations, assumptions, and the computer printout, This get proof that we did the job right. To summarize, when designing the air conditioning system, we should do the following: Use a computer program or written calculation procedure to size the system(Evaporator unit capacity and Condensing unit capacity).

4.3.1 Evaporator unit capacity

The capacity of any evaporator or cooling coil is the rate at which heat will pass through the evaporator walls from the cooled space to the vaporizing liquid inside and is expressed in (Btu/hr). As heat reaches the outside surface of the evaporator ,it must pass through the walls of the evaporator to the refrigerant inside by conduction. Therefore, the capacity of the evaporator that is the rate at which heat passes through the walls, is determined by the same factors that govern the rate of heat flow by conduction through any heat transfer surface and is expressed by the equation:

Layers	Thickness inch	Density Ib/ft2	Specific heat Btu/Ib F̊	R-value Hr ft2 F̊/Btu	Weight Ib/ft
Inside to outside Inside surface Resistance	0.00	0.00	0.00	0.685	0.00
Carpet	0.50	270	0.30	0.05002	11.3
3/8 in plywood	0.375	34	0.29	0.46642	1.10
Air space	0.00	0.00	0.00	0.9100	0.00
Build up flooring	0.375	70	0.35	0.33245	2.20
Out side surface resistance	0.00	0.00	0.00	0.33300	0.00
Total	1.250			2.78	14.5
Overall U-value	0.360 Btu/hrft2 f̊				

Table (3)

The U-value or the overall conductance factor represents the resistance to heat flow offered by the evaporator walls in the sum of three factors whose relationship is expressed by the following:

Since aircraft A\C system consists of two air packs and the area available in the aircraft is limited, therefore the evaporator coil into two sections and calculation were made for sizing each evaporator coil and the following results were gained. The data below showing the evaporator performance where the size of a coil is (16.0 in. x 28.0 in) and made of 4 rows.

Air Flow Rate	: 1900 cfm
On Coil DBT / WBT	: 78.0 °F / 65.5 °F
Coil Type	: Plain-3/8
Coil Size(H x L) / Rows / FPI	: 16.0 in. x 28.0 in. / 4 / 12
Coil Area	: 3.11 ft²
Face Velocity	: 514.3 fpm
By-Pass Factor	: 0.14
Air Pressure Drop	: 0.38 in.wg

	Condenser Entering Air Temperature (°F)				
	85.0	95.0	105.0	115.0	125.0
Total Capacity (MBh)	59.2	56.9	54.6	52.1	49.5
Sensible Capacity (MBh)	39.8	38.9	37.9	36.9	35.9
Power Input (KW)	4.7	5.1	5.5	5.9	6.4
Off-Coil DBT (°F)	55.1	55.6	56.2	56.7	57.3
Off-Coil WBT (°F)	53.3	53.9	54.4	55.0	55.6

Table (4)

A full design detail drawing of the evaporator section is shown in figure (4- 7) :

$$Q = A \times U \times \Delta T$$

Where :

Q = The quantity of heat transfer in Btu\hr

A = Cut side surface area of the evaporator

U = The overall conductance factor in Btu\hr

ΔT = The logarithmic mean temperature difference in degree (° F) between the temperature outside the evaporator and the temperature of the refrigerant inside the evaporator.

The U-value or the overall conductance factor represents the resistance to heat flow offered by the evaporator walls in the sum of three factors whose relationship is expressed by the following:

The evaporator coil is designed to be concealed in an air tight housing. The inlet return air from passenger compartment will flow in around duct , the evaporator coil and the outlet cooled air from evaporator is directed to the aircraft seating area in a round duct of 35 mm diameter. see table (4)

4.3.2 Condensing unit capacity

Since heat transfer through the walls of the condenser by conduction, condenser capacity is a function of the fundamental heat transfer equation:

$$Q_c = A \times U \times \Delta T$$

Where :

Q_c = Condenser capacity in Btu\hr

A = Surface area of the condenser in square feet

U = The overall heat transfer coefficient in Btu\hr

ΔT = Mean temperature difference between the condensing refrigerant and the condensing medium in °F.

The quantity and temperature rise of condensing medium can be calculated by using the following equations:

$$\Delta T = \frac{Q_c}{0.24 \times m}$$

Where :

m = Mass flow rate of air in the condenser in pounds per hour.

ΔT =Temperature rise of the condensing medium in the condenser.

$$m = \frac{Q_c}{0.24 \times \Delta T}$$

Condensing unit complete with condensing coil, fan and compressor were calculated by the use of SKM software and the following result were gained:

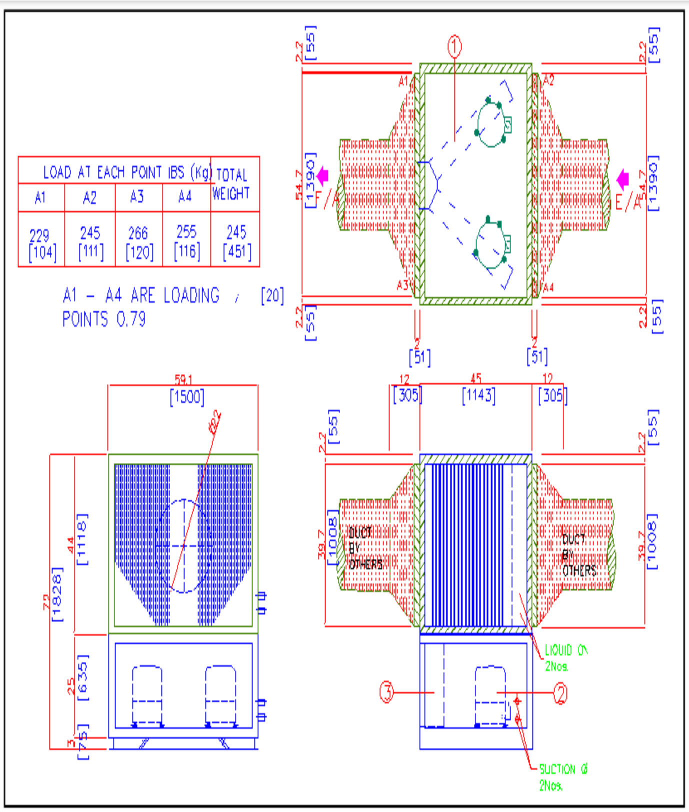
Fan / Quantity	: 1
Air Flow Rate	: 3500 cfm
Coil Type	: Plain-3/8
Coil Size(H x L) / Rows / FPI	: 36.0 in. x 36.0 in. / 4 / 12
Coil Quantity	: 1
Coil Area	: 9.00 ft²
Compressor Type	: Hermetic - R22
Compressor Model #1 / Quantity	: MT-64 / 1
Compressor Model #2 / Quantity	: MT-64 / 1
Power Supply	: 6 kw each compressor

SST	Condenser Entering Air Temperature (°F)									
	85.0		95.0		105.0		115.0		125.0	
(°F)	Cap (MBh)	PI (kW)	Cap (MBh)	PI (kW)	Cap (MBh)	PI (kW)	Cap (MBh)	PI (kW)	Cap (MBh)	PI (kW)
35.0	53.4	4.5	49.9	4.8	46.4	5.1	43.0	5.4	39.6	5.6
40.0	59.2	4.7	55.3	5.1	51.6	5.4	47.8	5.7	44.0	6.0
45.0	65.3	5.0	61.1	5.3	57.0	5.6	52.9	6.0	48.7	6.3
50.0	71.7	5.1	67.2	5.5	62.7	5.9	58.2	6.3	53.7	6.7

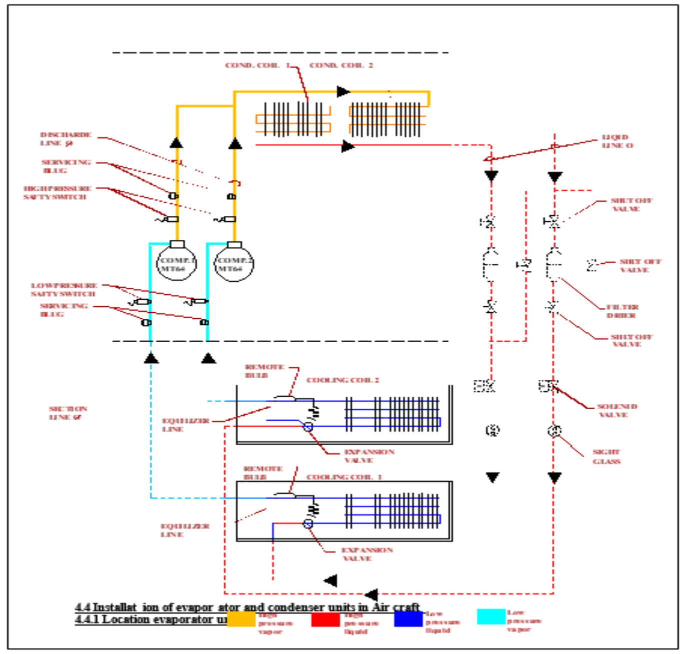
Table (5)

A full design were calculated and drawn, tacking into consideration the limited height of the area chosen to locate the condensing unit and taking into account the air discharge to be side way.

This will give a soft flow of ambient air to flow through the condensing coil from on side to other side and coal down the condensing refrigerant medium to the designed temperature.
A full detail of the condensing detail of the condensing unit is shown in figure (4-8), and figure (4-9) shows the refrigeration cycle with its component of a double stage *DX–spli* Air condition unit .

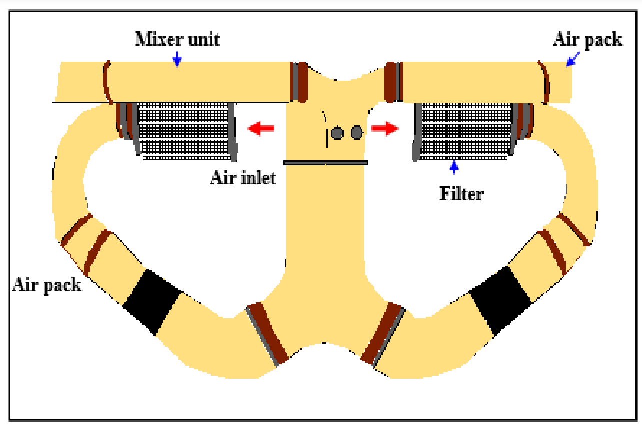


Figure(4-8) : A full detail of the condensing unit

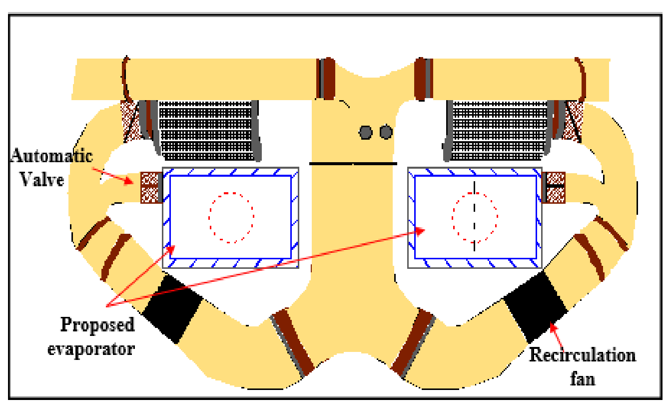


Figure(4-9) : shows the refrigeration cycle with its component of a double stage Air condition unit

Looking deeply into the existing air conditioning system , the A-320 aircraft is equipped with two air conditioning packs located in the wing root , the two air conditioning packs operate automatically and independently and feed air to a mixer unit .The conditioned air is distributed to the aircraft zones by the aid of two cabin recirculation fans.

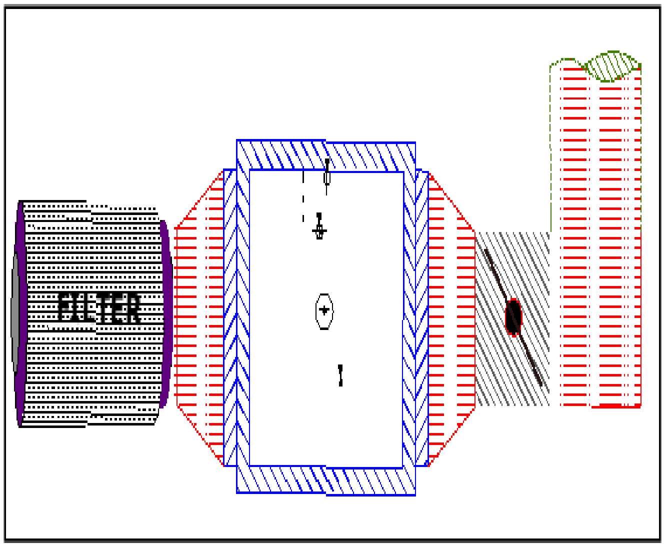


Figure(4-11) : Before installed the two evaporator units

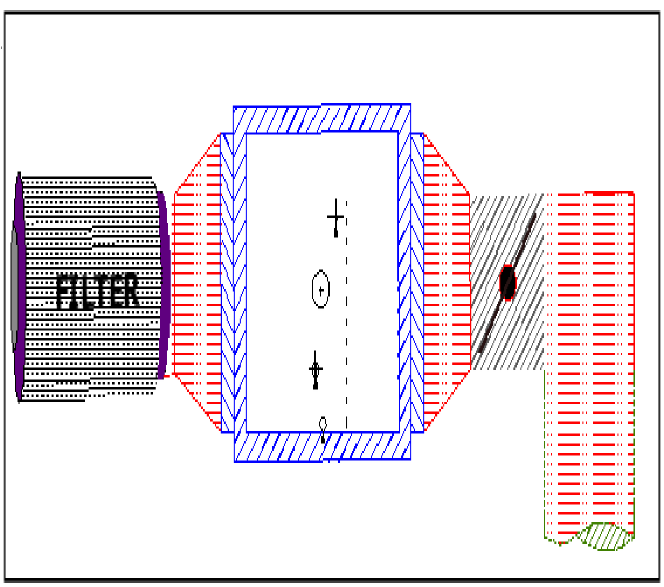


Figure(4-12) : After installed the two evaporator units

Further studies shown that the evaporator unit can be fitted in parallel with existing air packs and mixer unit, making benefit of using the same air duct, air outlets and re-circulating fan which are already existing. The two evaporator to be installed by fixing each unit in parallel with the existing air packs via an automatic shuttle of valve .figure (4-10) shown the location before installation the condenser and evaporator unit. See also figure (4-11) and figure (4- 12) .



Figure(4-13) : Right Side Evaporator Unit



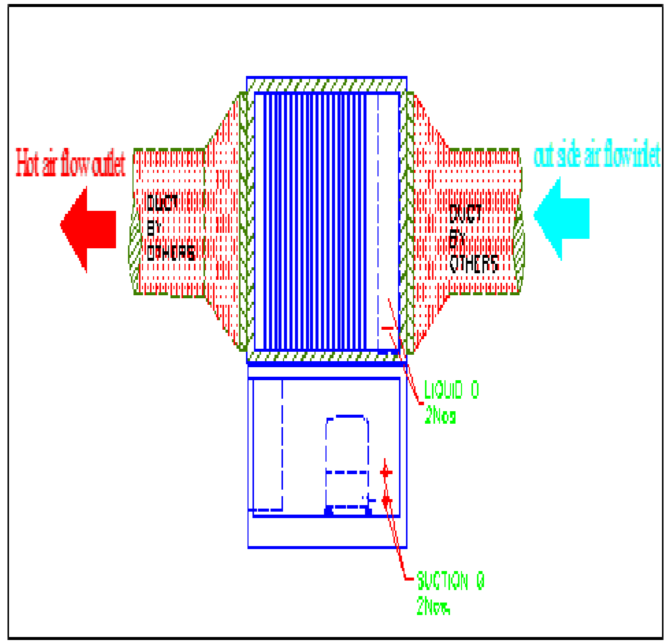
Figure(4-14) : Left Side Evaporator Unit

Figure (4-13) and figure (4-14) show the left and right

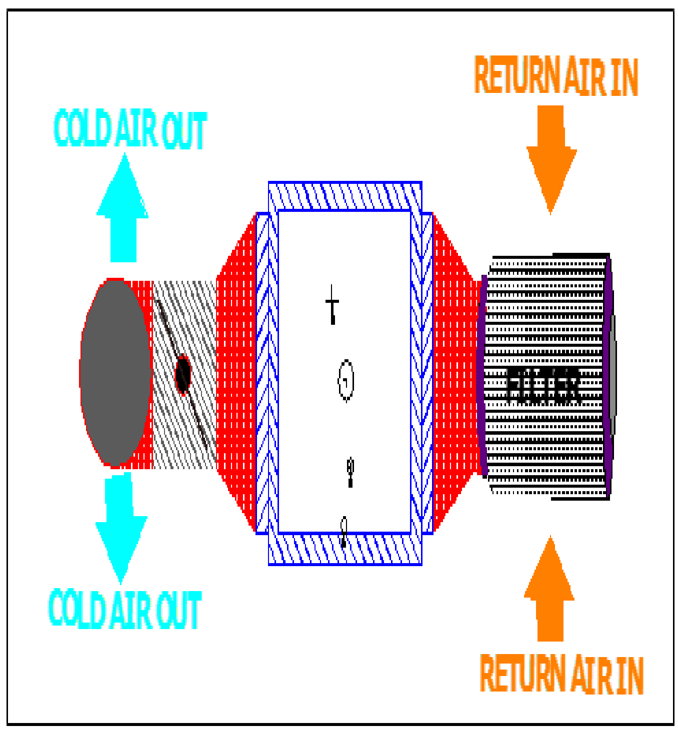
evaporator units. and Figure (4-16), show Air circulation in the new evaporating unit

4.4.2 Location condenser unit

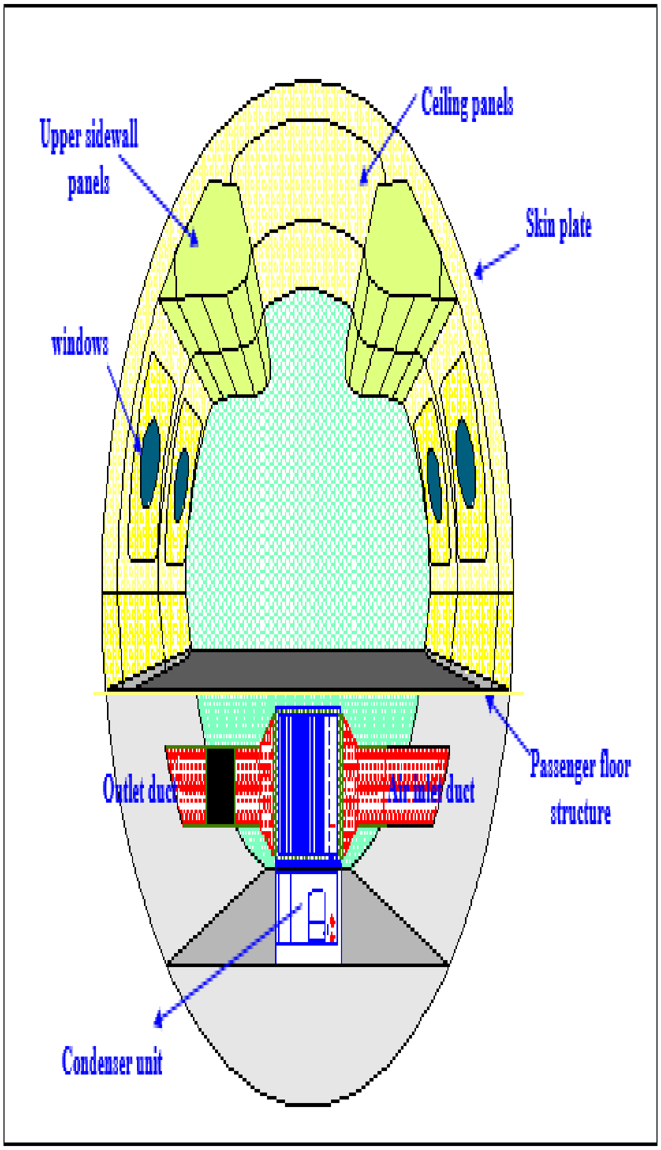
The section which consist as shown in figure (4-16) of type condenser coil , the compressor and the accessories for duct and refrigerant pipe connections.



Figure(4-16) :Air circulation in the new condensing unit



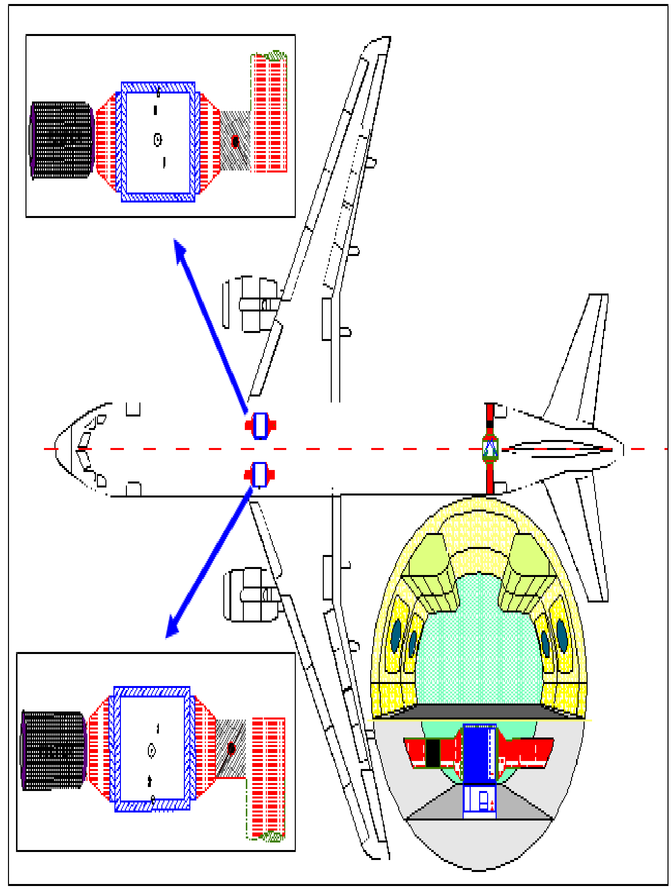
Figure(4-15) :Air circulation in the new evaporating unit



Figure(4-17) : Proposed location of condenser unit in air

After many discussion with the maintenance engineers of Kuwait Airways Company and with reference to our suggestion, it was decided to fix the condenser unit at the rear fuselage (Bulk Cargo) , making use of the opening at both sides of the airplane body to direct the ambient air to cool the condenser coil to the required designed temperature. The overall dimensions of the condenser is (1500 W x 1828 H) with total weight of (450 kg). Proposed location of condenser unit is shown in figure (4-17).

4.4.3 The position of evaporator and condenser units in Air craft



Figure(4-18) : Proposed location of condenser and evaporator units in air craft A320

After provides a full study and analysis to develop a new air conditioning system for Aircraft (A320), which can be operated while the aircraft is at the gate or during the critical time between the end of ground service and take off, we should located both evaporator and condenser units in Air craft ,so figure(4-18) show the proposed location of evaporator and condenser units in Air craft (A320) .

Discussion And Conclusion

5.1 Executive Summary and Conclusion

A number of systems have been developed over the years to satisfy the requirement of maintaining the temperature of the passenger cabin of modern day aircraft at a level that is comfortable to the passengers during the time the aircraft is parked. In such aircraft, the high density of passengers, the interior lighting, the large number of windows, and the heavily insulated fuselage all contribute to raising the temperature of the cabin of the parked aircraft to uncomfortable levels. Accordingly, it is necessary to provide a cooling system to lower the aircraft cabin temperature, even when the aircraft is parked in locations with relatively cool outside ambient temperatures. So this thesis provides a full study and analysis that leads to develop a new air conditioning system for Aircraft (A320), which can be operated while the aircraft is at the gate or during the critical time between the end of ground service and take off. The work was done attempting to state an idea that leads to implement a new air conditioning system for these modern aircraft offering safety and comfort for the passenger. To achieve this aim , it is important to understand the existing air conditioning system to ensure the compatibility of proposed system with the existing system, and that what I discussed in chapter (2).on the other hand I compared the existing air conditioning system with the two principle type of refrigeration plants found in industry in the same chapter. The next part of the thesis chapter (3) , I examined the aircraft body structure survey, and I focused on space characteristic and heat load sources then I measured not only the dimensions of the aircraft , but also climatic conditions. As a consequence of these study, the U-value of the air craft body structure and the heat sources were measured as shown in full details in chapter (4), given these data , an estimate of load calculation performed and generate the design report by the use of M/S carriers hourly analysis program (HAP). Based on the load calculation report, the needed capacity to cool the aircraft were calculated, and vapor compression refrigeration system was decide to be used for the production of needed cooling capacity. The air conditioning system were sized by using selection software offered by M/S Sharjah and Kuwait manufacturing company (SKM) and final capacities and dimension of evaporator and condenser units were decided. Finally , both evaporator and condenser units were fixed and installed at an appropriate location and a full detailed drawing of installing location were included in this thesis. The conclusion from this thesis work shows that it is possible to design anew system of air conditioning is to lower the aircraft cabin temperature, even when the aircraft is parked in locations with relatively cool outside ambient temperatures. It would be advantageous to provide a new air conditioning system that is adaptable to different operating requirements depending upon aircraft size, passenger load, ambient conditions, etc. In the future it is most probably that this new system of air conditioning will play a part in the development of the aircraft of tomorrow especially in hot and humidity countries.

References

1. Books

[1] Ashrea Handbook, HVAC Applications, SI Edition 1999.
[2] American Society Heating Refrigeration and Air Conditioning. ASHRAE Hand Book. 2001.
[3] Arora, C.P. Refrigeration and Air Conditioning. Second edition. Tata McGraw-Hill Publishing Company Ltd. 2000.
[4] Bureau of Energy Efficiency, Ministry of Power, India. HVAC and Refrigeration Systems. In: Energy Efficiency in Electrical Utilities, chapter 4. 2004.
[5] Aircraft Maintenance Manual (AMM) A320, Technical Data Support and Services, Airbus S.A.S 31707 BLANAC CEDEX, France, Customer Services, 2005.
[6] Structural Repair Manual (SRM) A320, Technical Data Support and Services, Airbus S.A.S 31707 BLANAC CEDEX, France, Customer Services, 2005.
[7] Modern Refrigeration and Air Conditioning, Andrew D. Althouse, Carl H. Turnquist, Alfred F. Bracciano, South Hollanda, Illinois, The Goodheart -willcox, inc 1988.
[8] Whalley, P.B. 1992. Basic Engineering Thermodynamics. Oxford University Press. ISBN: 0-19-856255-1.Haywood, R.W. 1980. Analysis of Engineering Cycles. Pergamon Press. ISBN: 0-08-025440-3

2. Unpublished manuscripts/ training papers

[1] A320, Technical Training Manual, 21 Air Conditioning, Category B1 Course, KUWAIT AIRWAYS, Engineering Training, Jan 2006.
[2] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/003 Book 1.March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[3] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/003 Book2 Part 1 March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[4] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/003 Book2 Part 2 March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[5] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/003 Part 3 March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[6] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/001 Part 1. March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[7] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Materials and Hardware, Part 66-C/001 Part 2. March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX TEL: 01738 877105.
[8] Air Service Training (Engineering) Limited, Subsidiary of Perth College, Environmental, Part 66-B1/005 Part 1.March 2006. Perth Collage, Brahan Building Creieff road Perth PH2 1NX, TEL: 01738 877105.
[9] Joint Aviation Authorities, Aircraft Maintenance Engineers Licenses, Theoretical Training Notes, Modules 6, Materials and Hardware, Oxford Aviation Training Limited 2000
[10] Joint Aviation Authorities, Aircraft Maintenance Engineers Licenses, Theoretical Training Notes, Modules 7, Maintenance Practices, Oxford Aviation Training Limited 2000
[11] Joint Aviation Authorities, Aircraft Maintenance Engineers Licenses, Theoretical Training Notes, Module 7, Rivitting, section 8, JAR 66 7.8.1.1 THRU 7.8.3.1, Oxford Aviation Training Limited 2000.
[12] Joint Aviation Authorities, Aircraft Maintenance Engineers Licenses, Theoretical Training Notes, Module11, Aeroplane Aerodynamics, Structures and Systems, section 01 ,Pneumatics, Vacuum (ATA36) JAR 11.16.1.1 THRU 11.16.6.1, Oxford Aviation Training Limited 2000.

3. Oral Sources and conversations

[1] Abdullah I. Khalil , (2009). Airframe System Engineer, Technical Development Section, Kuwait Airways, Engineering MT (interview).
[2] Umar Farooq Khan, (2009). Aircraft Mechanic, Kuwait Airways, Engineering Department (interview).
[3] Mohammad Shalash, (2009). Aircraft Mechanic, Kuwait Airways, Engineering Department (interview).
[4] Azzam Kazbour, (2009). Aircraft Engineer, Kuwait Airways, Engineering Department (interview).
[5] Mohammad Al-Fares, (2009). Aircraft Engineer, Kuwait Airways, Engineering Department (interview).
[6] Bashar Al-Najem, (2009). Aircraft Mechanic, Kuwait Airways, Engineering Department (interview).