Refrigeration and Air conditioning(BTME-4702)

Course Name: RAC

Semester: 7th

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Refrigeration

- The mechanism used for lowering or producing low temp. in a body or a space, whose temp. is already below the temp. of its surrounding, is called the refrigeration system.
- Here the heat is being generally pumped from low level to the higher one & is rejected at high temp.
- The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions.
- It also includes the process of reducing heat & maintaining the temp. of a body below the general temp. of its surroundings.
- In other words the refrigeration means a continued extraction of heat from a body whose temp is already below the temp. of its surroundings.

Refrigerator & Refrigerant

- A refrigerator is a reversed heat engine or a heat pump which takes out heat from a cold body & delivers it to a hot body.
- The refrigerant is a heat carrying medium which during their cycle in a refrigeration system absorbs heat from a low temp. system & delivers it to a higher temp. system.
- In refrigeration system the heat is being generally pumped from low level to higher one & rejected at that temp.
- This rejection of heat from low level to higher level of temp. can only be performed with the help of external work according to second law of thermodynamics

HEAT REJECTION

- The total amount of heat being rejected to the outside body consist of two parts:-

- the heat extracted from the body to be cooled .

- the heat equivalent to the mechanical work required for extracting it.

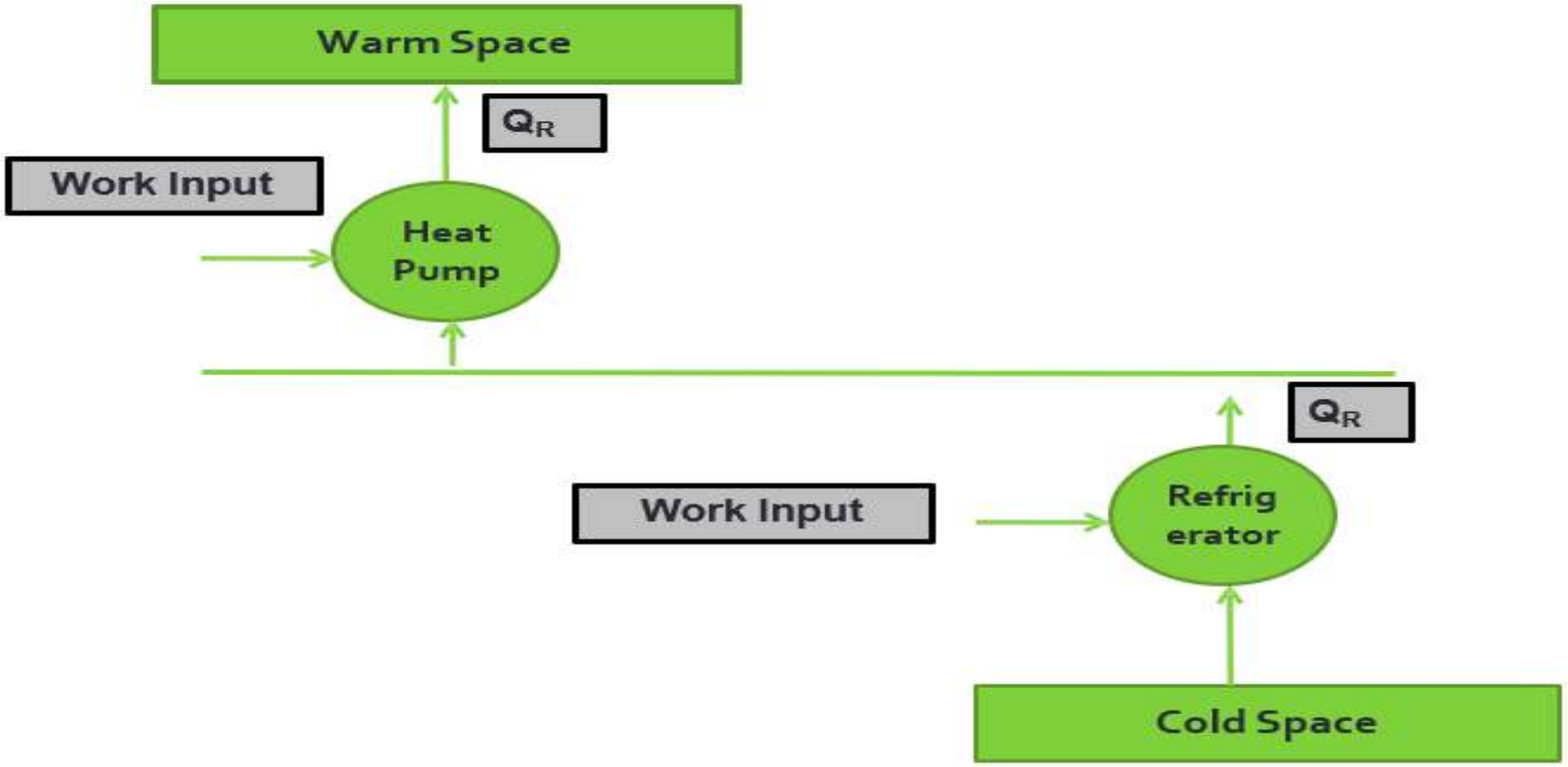
REFRIGERATOR

- A refrigerator is a reverse heat engine run in the reverse direction by means of external aid.
- Every type of refrigeration system used for producing cold must have the following four basic units:-
- Low temp. thermal sink to which the heat is rejected for cooling the space.
- Means of extracting the heat energy from the sink, raising its level of temp. before delivering it to heat receiver.
- A receiver is a storage to which the heat is transferred from the high temp., high pressure refrigerant.

REFRIGERATOR ANS HEAT PUMPS

- If the main purpose of the machine is to cool some object, the machine is named as refrigerator.
- If the main purpose of machine is to heat a medium warmer than the surroundings, the machine is termed as heat pump.

REFRIGERATOR AND HEAT PUMP



REFRIGERATION EFFECT

- **Refrigerating Effect (N):** It is defined as the quantity of heat extracted from a cold body or space to be cooled in a given time.
- N= Heat extracted from the cold space
    - Time taken
- **Specific Heat of water and ice :** It is the quantity of heat required to raise or lower the temperature of one kg of water (or ice), through one kelvin or (1^0
- c) in one second.
- **Specific heat of water, C_{pw} = 4.19 kJ/kg K**

Specific heat of ice, C_{pice} = 2.1 kJ/kg K.

1 TR(TONNE OF REFRIGERATION)

- **Capacity of a Refrigeration Unit :**
  - Capacity of a refrigerating machines are expressed by their cooling capacity.
  - The standard unit used for expressing the capacity of
- refrigerating machine is ton of refrigeration.
  - One ton of refrigeration is defined as, "the quantity of heat abstracted (refrigerating effect) to freeze one ton of water into one ton of ice in a duration of 24 hours at 0^o c".
- Heat extracted from at 0^o c = latent heat of ice
- Latent heat of ice = 336 kJ/kg
- i.e., 336 kJ of heat should be extracted from one kg of water at 0^o C to convert it into ice.

One ton of refrigeration = 336x1000 kJ/24 hrs.

$$= \frac{336 \times 1000 \text{ kJ/min}}{24 \times 60}$$

One ton of refrigeration = 233.333 kJ/min

= 3.8889 kJ/sec

COP

Co efficient of Performance: It is defined as the ratio of heat extracted in a given time (refrigerating effect) to the work input.

$$\text{Co efficient of performance} = \frac{\text{Heat extracted in evaporator}}{\text{Work Input}}$$

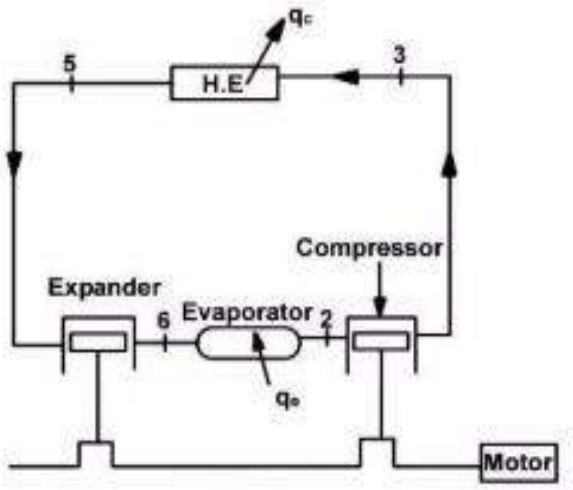
$$\text{Co efficient of performance} = \frac{\text{Refrigerating Effect}}{\text{Work Input}}$$

$$\text{Co efficient of performance} = \frac{N}{W}$$

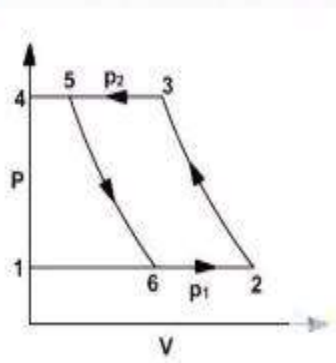
The COP is always greater than 1 and known as theoretical coefficient of performance.

AIR REFRIGERATION SYSTEMS

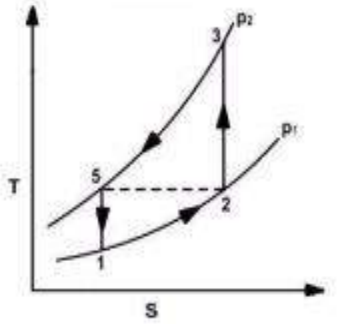
Air Refrigeration System And Bell-Coleman Cycle Or Reversed Brayton Cycle:



Air refrigeration system



Air refrigeration system



Air refrigeration system

The components of the air refrigeration system are shown in Fig. In this system, air is taken into the compressor from atmosphere and compressed. The hot compressed air is cooled in heat exchanger up to the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander.

AIR REFRIGERATION SYSTEMS

The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion. The low temperature air coming out from the expander enters into the evaporator and absorbs the heat. The cycle is repeated again. The working of air refrigeration cycle is represented on p-v and T-s diagrams in Fig.

Assumptions:

1) The compression and expansion processes are reversible adiabatic processes.
2) There is a perfect inter-cooling in the heat exchanger.
3) There are no pressure losses in the system.

AIR Refrigeration System For Aircraft Cooling

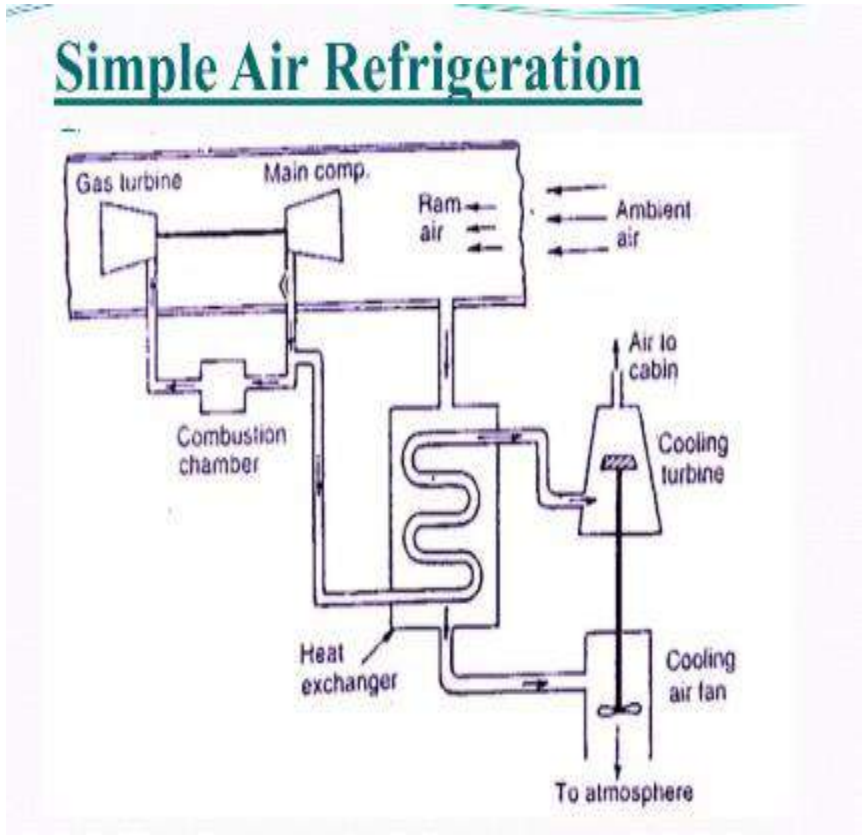
- **Application Of Aircraft Refrigeration**

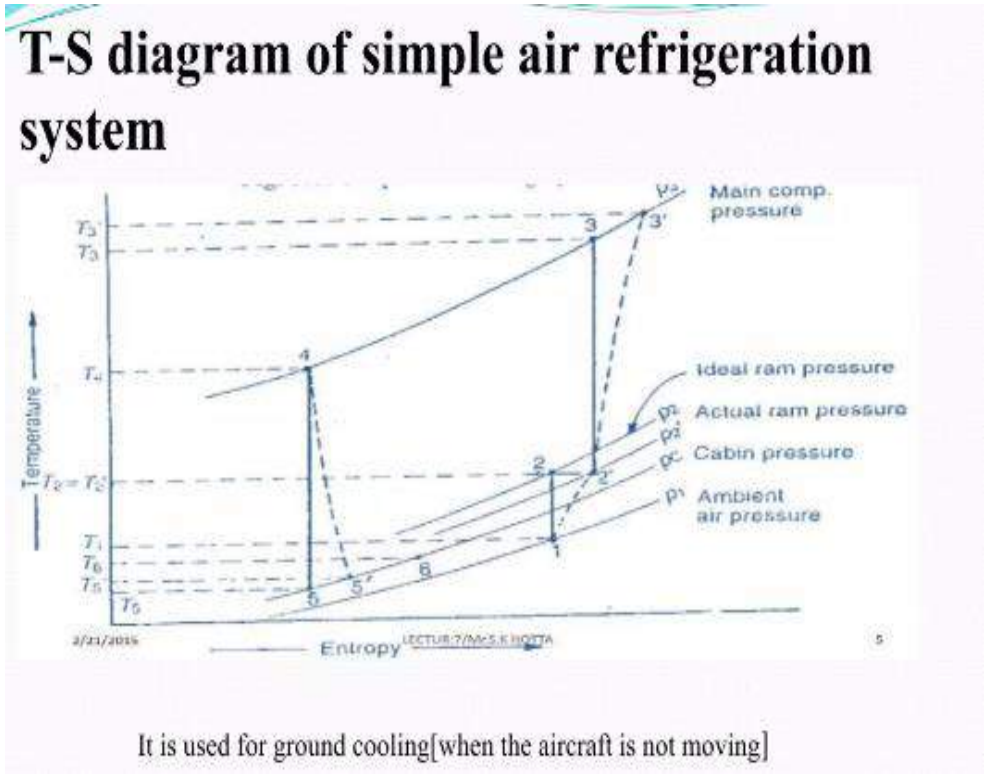
  - External heat gain due to solar radiations.
  - Heat released by the occupants.
  - Internal heat gain due to electrical and mechanical equipment used.

- **Types Of Air Refrigeration System**

  - Simple air refrigeration system.
  - Bootstrap air refrigeration system.
  - Regenerative air refrigeration system.
  - Reduced ambient system

AIR REFRIGERATION SYSTEMS





It is used for ground cooling[when the aircraft is not moving]

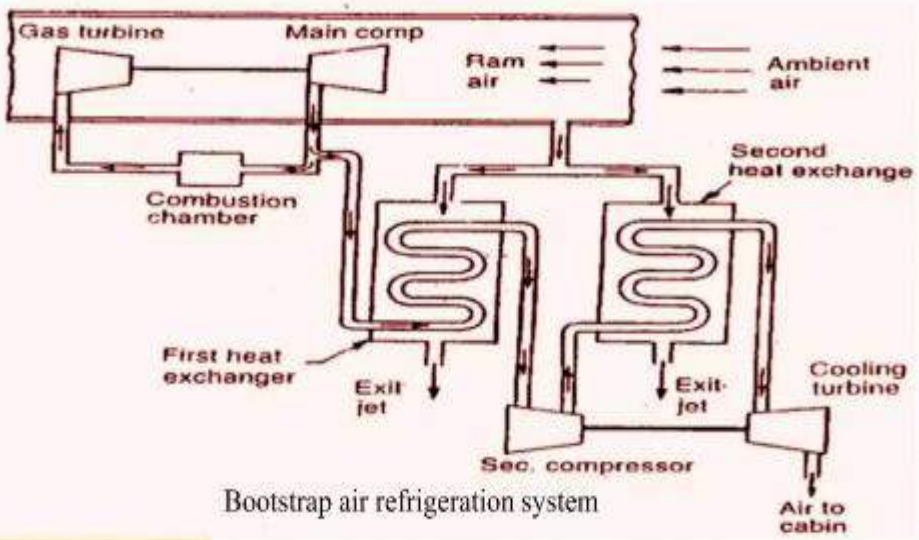
AIR REFRIGERATION SYSTEMS

Simple Air Refrigeration System

- In the simple system shown in figure the compressed air after cooling in air cooler is passed through a cooling turbine.
- The work of this turbine is to drive a fan which draws cooling air through the heat exchanger.
- The air is discharge from turbine at a pressure slightly above the cabin pressure.
- The fan is put on the down stream side thus avoid the additional temperature rise of the cooling air.
- This system is good for ground cooling since the fan driven by the turbine is a source of providing cooling air for the heat exchanger.
- However the turbine work is not available for the compressor.

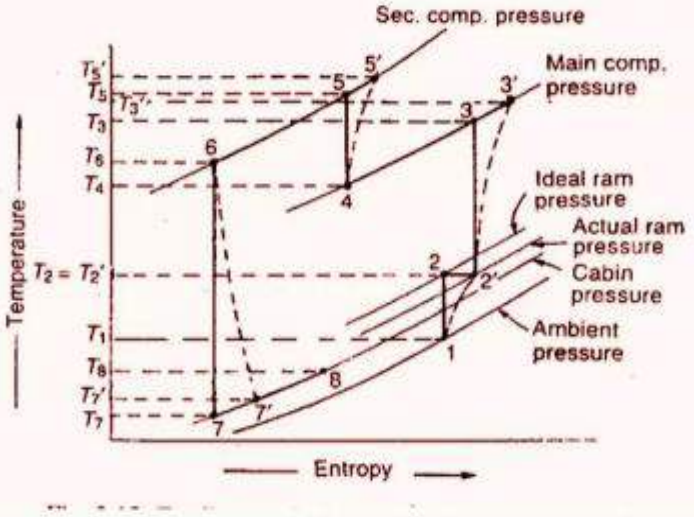
AIR REFRIGERATION SYSTEMS

Bootstrap Air Refrigeration System



Bootstrap air refrigeration system

T-s Diagram of Bootstrap System



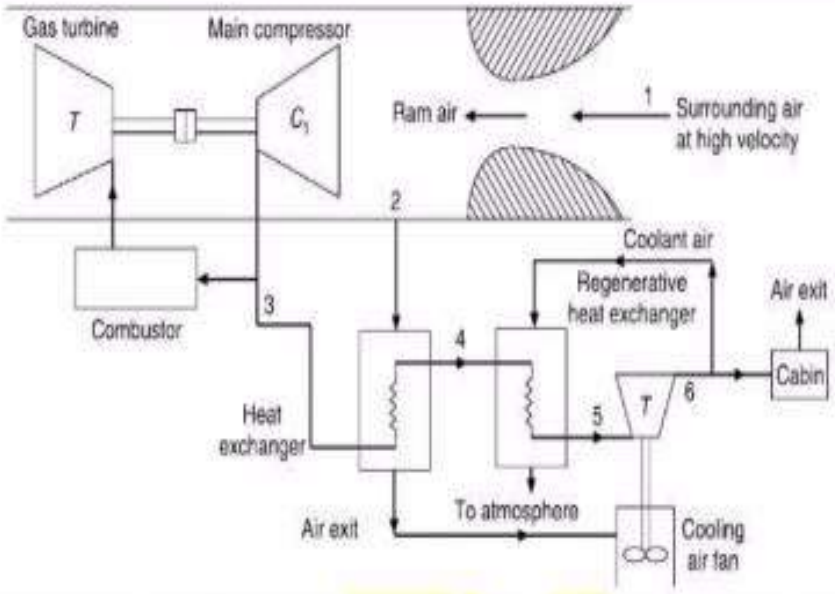
It is used in a high speed aircraft

AIR REFRIGERATION SYSTEMS

Bootstrap Air Refrigeration System

- The Bootstrap system shown in figure has two heat exchangers instead of one and the expansion turbine drives a compressor rather than a fan.
- Thus it cannot be used for ground cooling.
- The primary purpose of Bootstrap system is to provide an additional cooling capacity when the primary source of air does not have a sufficiently high pressure to provide the amount of cooling required.
- The turbine drives the secondary compressor to rise the pressure of primary air before it enters the turbine .
- It is used for high speed aircraft where in the velocity of the aircraft provides the necessary airflow for the heat exchangers ,as a result a separate fan is not required.

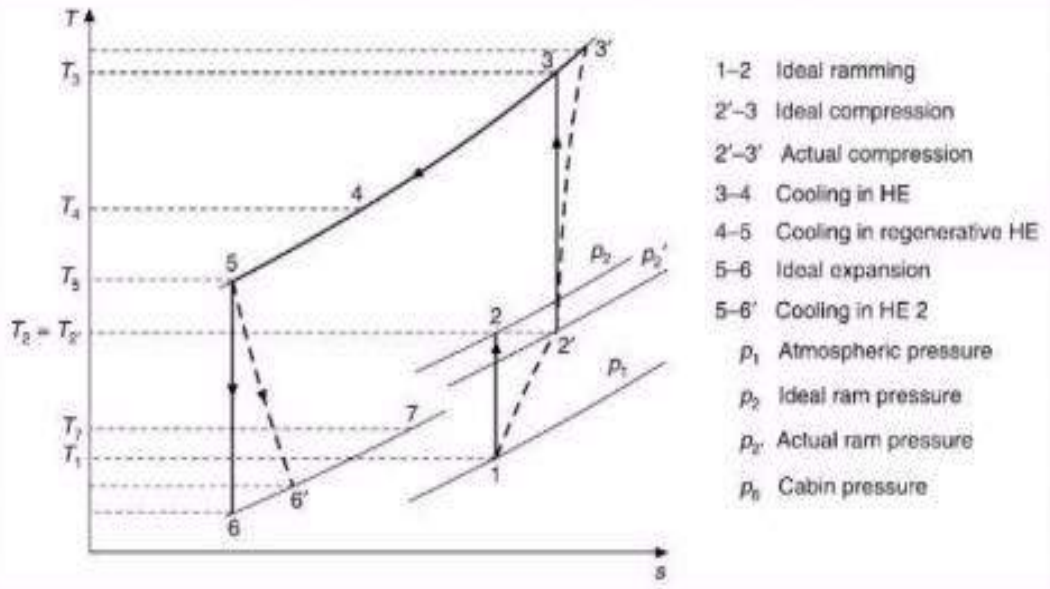
Regenerative Air Refrigeration System



Regenerative system

AIR REFRIGERATION SYSTEMS

T-S Diagram of Regenerative System



It is used for ground cooling as well as high speed aircrafts

Regenerative Air Refrigeration System

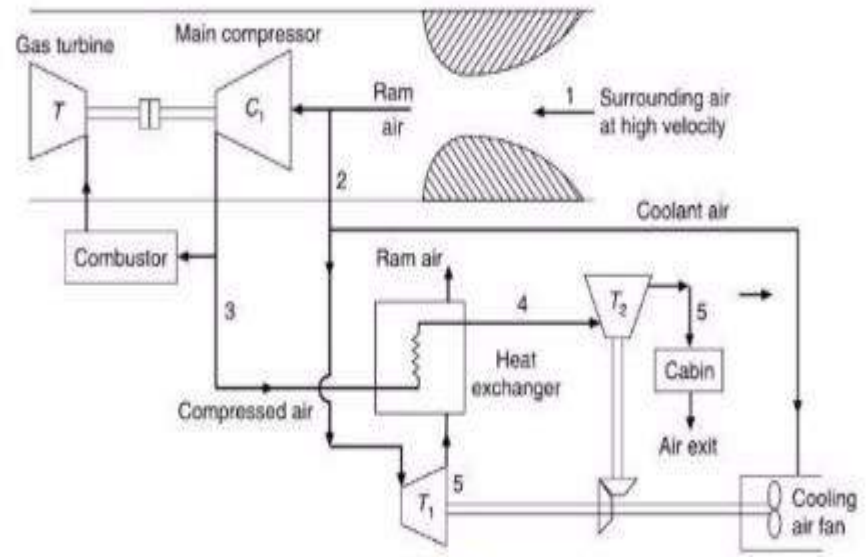
The regenerative system shown in figure also has two heat exchangers but does not required ram air for cooling the air in the second heat exchanger.

It is a modification of the simple system with the addition of a secondary heat exchanger in which the air from the primary heat exchanger is further cooled with a portion of the refrigerated air bled after expansion in the turbine as shown in figure.

It provides lower turbine discharge temperatures but at the expense of some weight and complications.

AIR REFRIGERATION SYSTEMS

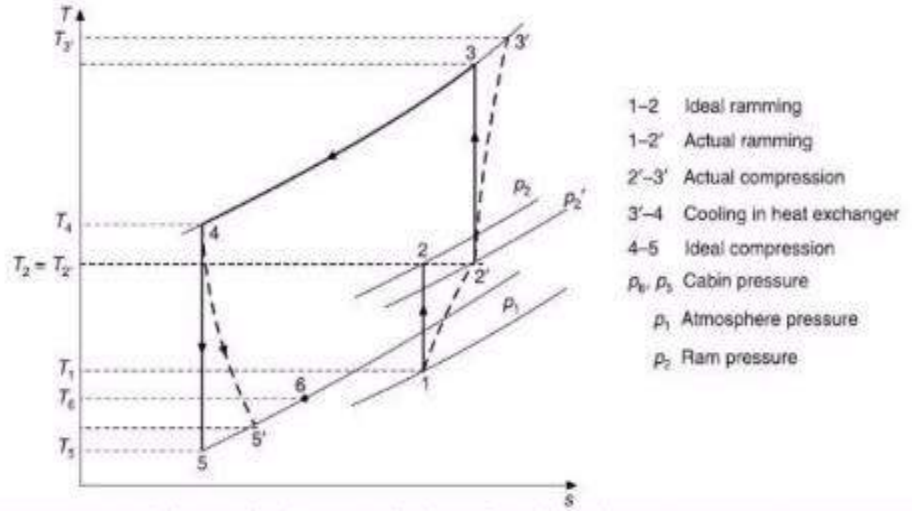
Reduced Ambient System



Reduced Ambient Air Refrigeration System

Reduced Ambient System

T-S Diagram of Reduced Ambient System



It is used in Supersonic aircraft and Rockets.

AIR REFRIGERATION SYSTEMS

Dry Air Rated Temperature (DART):

The concept of Dry Air Rated Temperature is used to compare different aircraft refrigeration cycles. Dry Air Rated Temperature is defined as the temperature of the air at the exit of the cooling turbine in the absence of moisture condensation. For condensation not to occur during expansion in turbine, the dew point temperature and hence moisture content of the air should be very low, i.e., the air should be very dry. The aircraft refrigeration systems are rated based on the mass flow rate of air at the design DART. The cooling capacity is then given by:

$$\dot{Q} = \dot{m} c_p (T_i - T_{DART}) \qquad (9.27)$$

is the mass flow rate of air, T_{DART} and T_i are the dry air rated temperature and cabin temperature, respectively.

A comparison between different aircraft refrigeration systems based on DART at different Mach numbers shows that:

i. DART increases monotonically with Mach number for all the systems except the reduced ambient system

ii. The simple system is adequate at low Mach numbers

iii. At high Mach numbers either bootstrap system or regenerative system should be used

iv. Reduced ambient temperature system is best suited for very high Mach number, supersonic aircrafts

Summary

- In this chapter, concept of refrigeration discussed along with applications
- Differentiating refrigerator with heat pump
- Air refrigeration systems and its various types

Topics to be Discussed in Next Lecture

- Vapour Compression cycle