ADIABATIC TEMPERATURE CHANGES

It is necessary at this point to consider the very important changes in the temperature of air which occurs as it is moved upward away from the earth or downward toward the earth. As air moves upward away from the earth, it comes under lower pressures, for there is less weight of air upon it and consequently it expands. Conversely as air moves downward toward the earth from high elevations its encounters higher pressures and contracts in volume. Thus, if a mass of dry air at sea level, under an atmospheric pressure of approximately 1,016 mb, or 30 in., rises to an altitude of 17,500 ft., the pressure on it is reduced about one-half and consequently its volume is doubled. A cubic foot of air at sea level would then, if carried to that altitude, occupy 2 cu. ft. Through these expansion and contraction processes associated with changes in elevation the temperature of the moving air changes even though there is no actual addition or withdrawl of heat. This type of temperature change resulting from internal processes is called <u>adiabatic change</u>.

According to the molecular theory a gas such as air is composed of molecules which are in a state of constant motion, so that there are persistent collisions between individual molecules. The impact of colliding gas molecules produces the pressure of the gas. The pressure, therefore, depends upon the number and mass of the molecules and the speed at which they are moving, which in turn is determined by temperature. If the temperature is high, the

and the number
molecular velocity is greater and the number collisions more frequent. Therefore, the gas pressure is greater at high temperatures than at low temperatures. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ ∴ P & V are directly related, T & P.V are in

Some of these principles indicating the relationship between pressure, temperature and volume (hence also density) in gases may be expressed in the form of physical laws as follows :—

(a) In a gas kept at constant temperatures the volume is inversely proportional to the pressure. If pressure on the gas is doubled, its volume is reduced one-half.

(b) In a gas kept at constant pressure the volume varies directly with the absolute temperature. Therefore, as the temperature of a gas increases, its volume also increases, as its temperature is lowered, its volume is decreased.

In making use of the above gas laws, it becomes clear that a mass of air which is lifted will experience a decreased pressure upon it, so that its volume is increased. In addition, work is done by the expanding air in making room for itself and this work done in pushing aside the surrounding air requires energy which results in a lowering of the temperature of the rising air. Since the volume of the expanding air has been increased, the collision of the molecules is less frequent and temperature consequently falls, conversely when air descends, its volume is decreased by the greater air pressure and its temperature and density are increased.

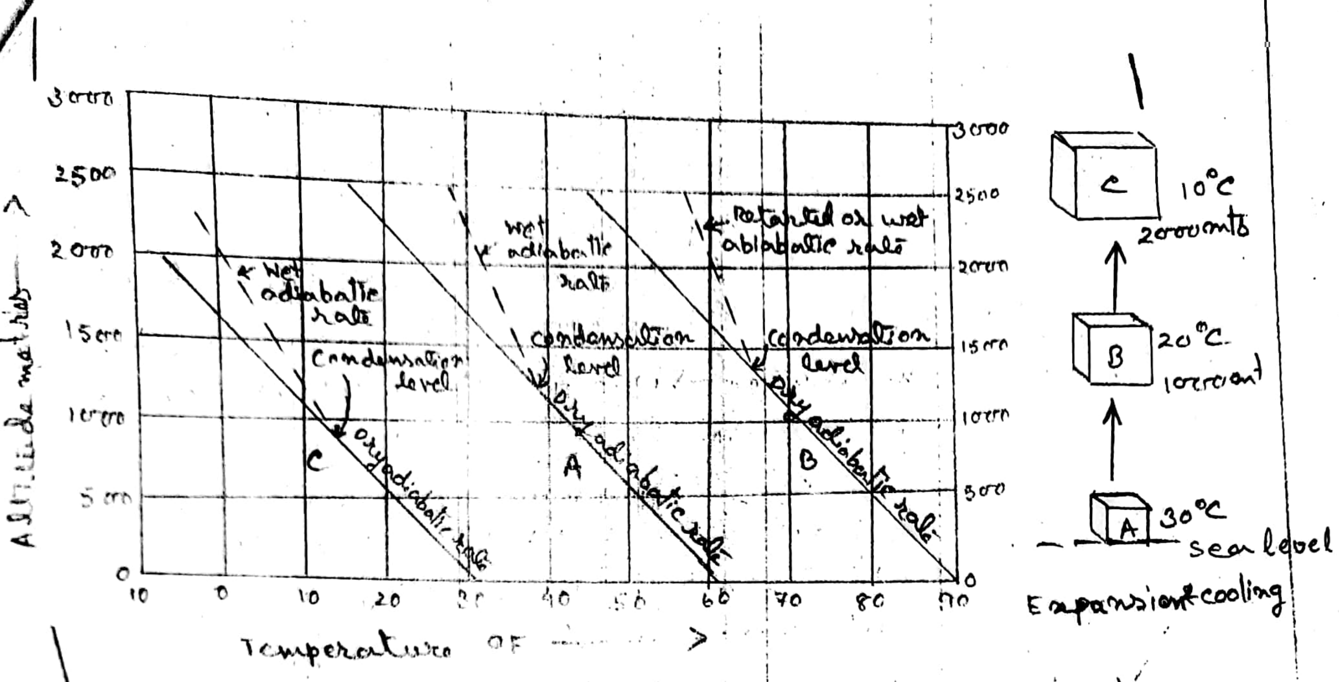

Fig. 1. Illustrating adiabatic cooling in rising air of different temperatures.

The rate of adiabatic heating and cooling of dry or non saturated air masses through vertical movement is constant, no matter what the temperature of the air. It is approximately 5·54°F per 1,000 ft. change in altitude or 10°c per 1,000 mts. This is known as the dry adiabatic rate, for it applies only to air which is not saturated. The rate of cooling of ascending air, therefore, is considerably more rapid than is the normal vertical decrease in temperature (lapse rate) which is about 3·3°F per 1,000 ft or 6°c per 1,000 mts. These two rates should be clearly distinguished as being very different things, for one represents the cooling of a rising and therefore vertically moving air mass, while the other applies to the change in air temperature that would be recorded by a thermometer carried up through the atmosphere.

The Moist or Retarded Adiabatic Rate —

As indicated previously, the adibatic rate of cooling for unsaturated air is the same, no what the temperature. For this reason, the th dry adiabats in Fig 1. are all parallel. But as the unsaturated air continues to rise and cool, it is likely to reach a temperature at which condensation begins. This is called the <u>condensation level</u>. It will be noted in Fig 1. that the condensation levels for the three rising air masses, each of a different temperature, are not the same. This results from likely differences in relative humidity. Thus the cooler air, c, which normally would have the highest relative humidity, reaches condensation level first or at the lowest elevation. The warmest air B, which has the lowest relative humidity has to rise higher and reach a lower temperature before the saturation point is reached and condensation begins.

After the rising air reaches the condensation level, where clouds begin to form, the then saturated air as it continues to rise cools no longer at the previous dry adiabatic rate, but at one which is somewhat slower. This is called the <u>retarded</u> or <u>wet adiabatic rate</u>. Above condensation level where water vapour is being converted into clouds composed of liquid and ice particles, heat of condensation is released into the atmosphere. It is this added source of energy which slows up the rate of cooling in the ~~atm~~ rising air. Two counteracting processes, one resulting in cooling and the other in heating are proceeding simultaneously, for while the saturated air continues to cool by expansion, the heat liberated as a result of condensation acts as a brake on the cooling process. Of the two processes, the cooling due to expansion is the primary one, with the result that the rising saturated air continues to cool but at slower rate.

It may be observed from fig 1. that the retarded, or wet adiabatic, rate is not constant, but varies with the temperature of the air. The same amount of cooling will result in the condensation of a greater amount of moisture when air temperature is high because the specific humidity of warm air is higher than that of cool air. As a result, the amount of liberated heat of condensation is much greater at high temperatures and as a consequence the wet adiabatic lapse rate is smaller in 90° air than in 30° air. When air temperatures are extremely low, the moisture content is so low that the wet adiabatic lapse rate is almost the same as the dry adiabatic rate. As high temperatures the wet adiabatic rate may be in the neighbourhood of one-half the dry adiabatic rates or about 3° per 1,000 ft.