TRONIC CLOUD CHAMBER - refrigeration based miniaturized cloud chamber

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1. Introduction

The study of cosmic rays has always brought up interesting investigations. In physics, this topic has very active research. In 1924,Blackettand co-workers used the cloud chamber to observe the transmutation of nitrogen into fluorine, which then disintegrated into oxygen**[1]**. Anderson and co-workers in 1933 discovered anti-electron, the positron in cloud chamber**[2]**. In 1947 Rochester and Butler published the first cloud chamber images showing evidence for **kaon [3]**. When the modern particle accelerators were not invented, cloud chamber was a simple device and efficientmethod to study the cosmic particles**[4]**. The cloud chamber was further modified by Stuart Blackett, giving it more number of applications**[5]**. Cloud chambers operate with two methods which are liquid in the sealed box, and method of cooling **[6]**.

The first cloud chamber was invented by Wilson in the year 1911**[7]**. Wilson investigated the effects of sunlight on the clouds around the mountain, and reproduced them in a laboratory. Wilson used X-rays for this study as the illumination wave. He observed minute streaks and patches of cloud throughout the region in the path of the beam. The clouds were mainly short thread-like objects, few of them moving in straight lines and some of them even looping round.Wilson saw this as a very direct proof that X-rays liberated energetic electrons in the gas, and that these electrons caused ionization along the path of the X-rays. Wilson modified his cloud chamber by 1912, and used it to produce many photographs of the alpha, beta and X-ray tracks. With his cooperation cloud chambers were manufactured commercially by the Cambridge Scientific Instruments Company, and remained the principle detector for studying particle tracks until the invention of the bubble chamber in the 1950s**[8]**.

Using this instrument at CERN, FERMILAB experimental physicists have discovered many properties that shaped our understanding of quantum physics **[9]**.

When a particle is passed through the supersaturated vapors, droplets are formed on the line due to ionization along the track and particle is detected is the principle behind Wilson’s cloud chamber [7]. However tronic cloud chamber is based on the refrigeration principle where in a coolant is circulated through the system which efficiently transfers heat from the region to be cooled and dissipates it through the condenser according to thermodynamic principle**[10]**.

The method of cooling has been used as experiments in this study. Modern magnetic techniques influence the flow of liquid in the sealed box in such a way that it reaches super saturation state. Alternatively, there is dry ice which is commonly used to cool it down. Magnetic techniques don’t help much as they require a constant supply of electricity. This limits the study at an isolated place where cosmic radiations of interest are present. Further, even with the supply of electricity, the experiment is tampered with particles knocked off from the wires hence limiting the possibility of studying cosmic particles **[11]**.Further, it has been found that dry ice is not eco-friendly, since at the lower temperature it has to be handled carefully and also sublimates quickly**[12]**.

No work has been done till now to solve these two issues. In this study, we have developed a novel method to address these problems with an application of engineering tools to cool it in a miniature scale. The usability of this method limits above micro scale cooling. The method uses refrigeration principle as basis and combined with other thermodynamic properties helps cool the system more efficiently and much lower temperature can be attained relative to the original invention .The miniature device ensures that it is easy to carry and experiment can be conducted in isolated conditions ensuring the study of cosmic rays. The next section describes the experiments performed in this study.

2. Materials and methods

A rectangular box of 510 mm x 180 mm x 700 mm was in – house fabricated with glass and filled up to80% of height with pure ethanol. The box was placed over aluminium plate which acted as heat sink. Below the heat sink, in its contact, coiled copper pipes were placed in, which in turn were connected to small pipes carryingaqueous solution of anhydrous ammonia as coolant. The setup has been shown in figure 1.

Figure 1: Cloud chamber fabricated from glass

As shown in the figure above, the coolant was stored in a tank connected in series with the pipe line from the copper tubes. The coolant was circulated throughout the system and it absorbed heat from the chamber through heat sink and dissipated the heat through the condenser as shown in the schematic given in figure 2.

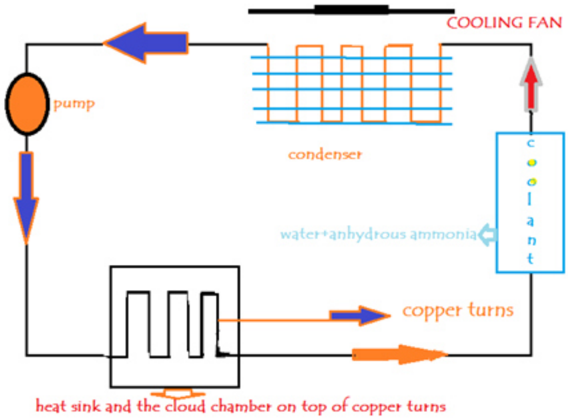

Figure 2: Schematic of the heat flow through the chamber

The pump worked on 12V DC supply for the circulation of the coolant. The circulation of air and also efficient transfer of heat was facilitated by attaching a condenser with a cooling fan.

The chamber was cooled to 2 ^{0}C before we initiated the detection. The pressure was maintained at 1 atm throughout the experiments. The glass chamber was exposed to cosmic rays. The cosmic rays are visible with the trails they leave behind after passing through it. The alpha, beta particles were observed and identified based on their individual behaviours like thickness of the trail etc.

3. Results and discussions

The chamber after initial cooling has been shown in figure 3.

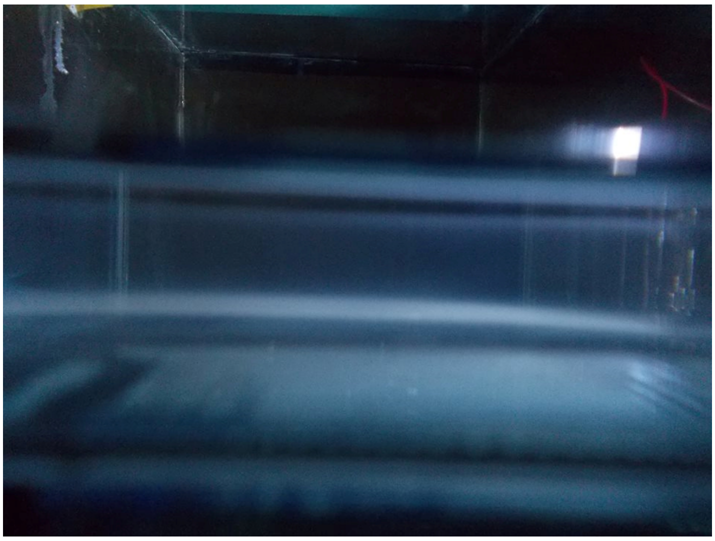

Figure 3: Picture of the chamber after initial cooling

The picture shown in figure 2 was captured before the gas inside the chamber reached super saturation state.

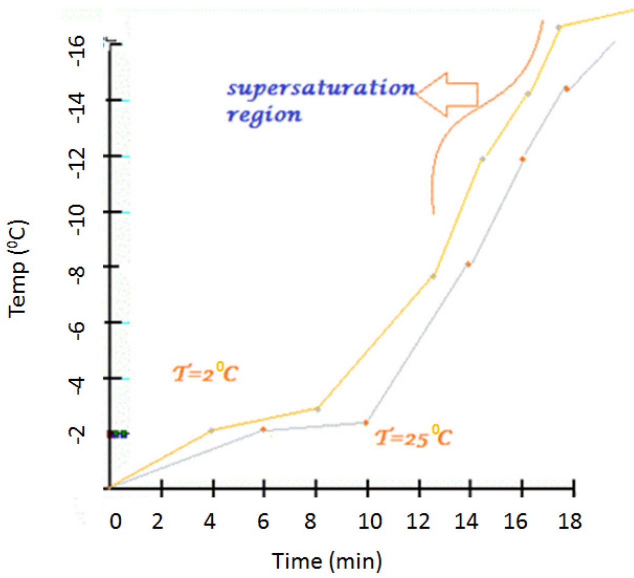

Figure 4: Cooling cycle of the chamber

This plot shows the cooling of the alcohol (liquid) with time. We see that the temperature gradually decreased. The slope at any two points on the graph indicates the rate of change of temperature, $\frac{dT}{dt}$. The graph indicates the slope is negative hence temperature of the alcohol reduces with time. However after it reaches below -16 ^{0}C the slope approaches zero indicating the transition of alcohol from liquid to solid state. The curve represented at 2 ^{0}C was recorded at an altitude of 4115 m whereas the curve at 25 ^{0}C was recorded at an altitude of 290 m above the sea level. The temperature gradient suggests that the cooling is not Uniform however the cooling slows down from -16 ^{0}C ensures the longevity super saturation state. This ensures that conditions were optimal for the experiment.

The temperature difference between the upper part and the bottom of the chamber is responsible for attaining super-saturation state. The larger differences are desired for better results. While at super saturation state, a charged particle that crosses the chamber causes ionization along its path. The vapor condenses about the ions, and the particle's path is traced out as little wisps and threads of cloud. The mechanism at work here is the same as the one that sometimes gives rise to condensation trails (contrails) in the wake of an airplane **[13]**.
The observation of cosmic ray trails start appearing with -12^{0}C while still cools to lower temperature. The thick lines represent high energy alpha particle, long thin trial lines represent muons and thick trial lines of long tracks represent beta particles. Since it is advised that one finds an isolated place and also higher altitude and lower temperature for better results, tronic cloud chamber is tailored for such conditions.Low momentum tracks produced by low momentum muons and electrons are easily be deflected by the magnetic field. Measuring the particle's radius of curvature in a known magnetic field of earth reveals its momentum. At sea level, where this chamber was developed and operated, it is rare. Most decays are muons decaying into electrons **[14]**.

As observed electrons scattered most in cloud chamber, muons did not relatively. In rare occasions, delta rays were seen by looking at long tracks in the chamber. As a high energy particle blasts through, small branches form. The branches are due to Rutherford scattering.Since the momentum of the particle generally decreases, the path radius diminishes slightly offering an opportunity to discuss the momentum lost by the particle.

4. Conclusions

The above novel cloud chamber developed in this study is easy to carry and assemble owing to its simple construction. We have also probed into the scope of improvement in the Wilson's cloud chamber. We have made an attempt to study cosmic rays with ease by controlling the temperature in an efficient way.

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