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FROZEN AMMONIA MICROPELLET GENERATOR FOR BASEBALL II-T

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FROZEN AMMONIA MICROPELLET GENERATOR FOR BASEBALL II-T*

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Background

We decided to provide a "startup" plasma at the center of the Baseball II-T magnet. This startup plasma will be used as a target for high energy neutral beams to achieve the required build-up. The target plasma will be created by irradiating a solid pellet with a laser beam. Although a deuterium pellet would be superior because of purity, the development of an ammonia pellet was undertaken because it requires a simpler technology.[1] The ammonia target plasma is physically acceptable for the initial experiment. A frozen ammonia pellet, about 100 μm in diameter, will be irradiated with 300-J CO_2 laser,[2] to produce a density of about 10^{13} cm^{-3} and about 1 kV temperature. See Fig. 1 for the general layout of the Baseball II-T experiment.

Discussion

The apparatus for producing, charging, accelerating, freezing, guiding and transporting the pellet to the target zone consists of the following elements:

Pellet Generator

The geometric arrangement of the pellet generator and the pellet transport system is shown in Fig. 2. Ammonia gas is liquefied and transferred to a pellet gun (Fig. 3) for gas supply systems. The pellet gun is a glass capillary bonded to a stainless steel tube, mounted in such a way that it has five degrees of freedom of movement for aligning the pellet trajectory. A liquid ammonia jet is produced through the capillary. Rayleigh showed[3] in 1878 that liquid jets are

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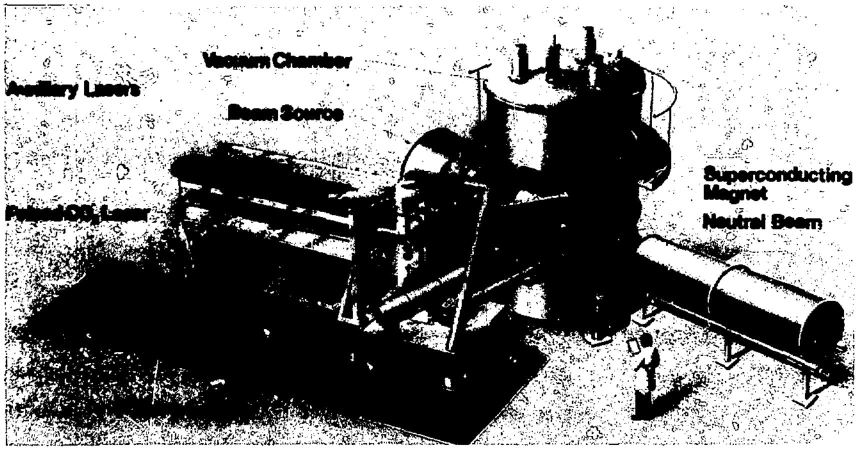

Fig. 1. Baseball II experimental layout.

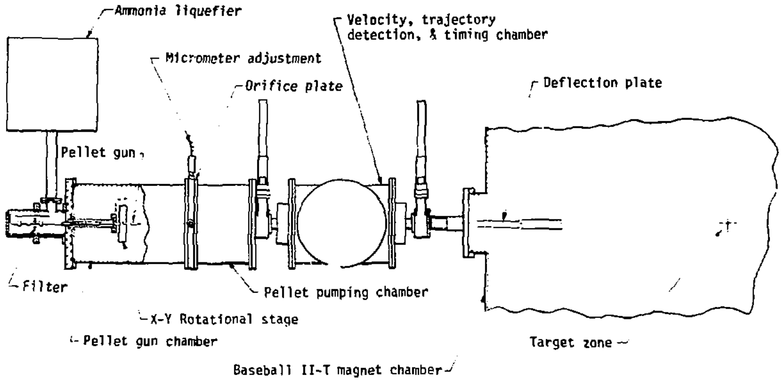

Fig. 2. Ammonia pellet generator and transport system.

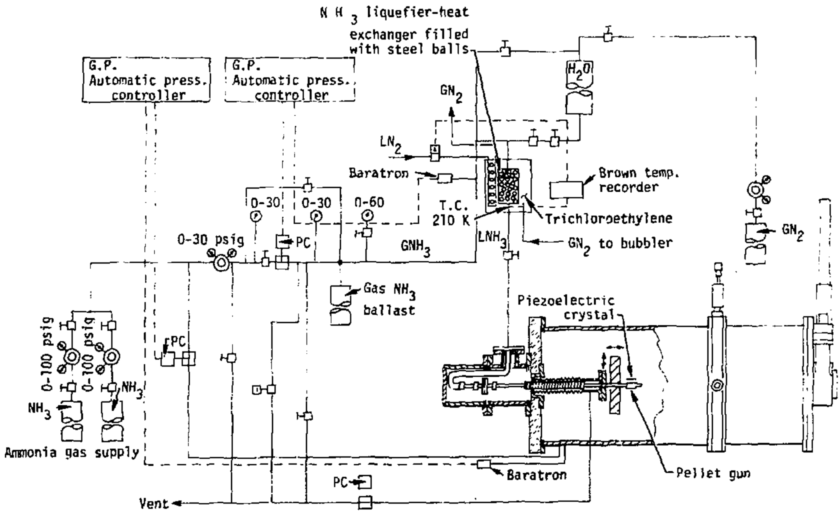

Fig. 3. Ammonia pellet generator NH_3 gas supply system.

(Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research and Development Administration to the exclusion of others that may be suitable.)

inherently unstable and break into droplets. On the other hand, the droplet size can be controlled by controlling the disturbance applied to the capillary producing the liquid jet[4] (Fig. 4). The pellet gun is disturbed with a piezoelectric crystal mechanically attached to the gun and pulsed up to 18 kHz. By using a proper size nozzle and selecting the required crystal frequency, we have produced pellets of 40 to

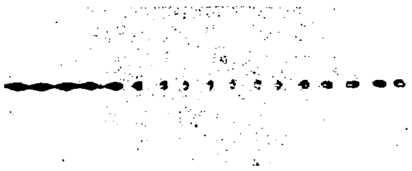

Fig. 4. Pellet stream.

200 μm in diameter at a rate of up to 18 000/s. The initial velocity of the pellet as it is formed in the pellet gun chamber is about 10 m/s.

Charging, Skimming, and Pellet Accelerating Scheme

The liquid ammonia pellets are charged by using two washers placed in front of the pellet gun as shown on Fig. 5. Selected ammonia[5] pellets are charged by an electric field of 5×10^4 V/m for about 50 μs. The field is applied axially between the washers. The charging pulse-rate[6] varies from 20 pps to 3200 pps. The low electrical conductivity of pure anhydrous liquid ammonia made it difficult to charge the liquid ammonia pellets. However, this was solved by adding small amounts of ionic impurities (~3%) in H_2O to provide charge carriers. The charged liquid pellets are lifted about 2 mm from the neutral stream by a static electrical field applied normal to the stream. The neutral pellet stream is deflected by a skimmer plate, which allows only the charged pellets to proceed through the orifice plate. An orifice, with a 2.29-mm diameter[7] (Fig. 6) between the pellet gun and the pellet pumping chamber accelerates the pellet.[8] The pressure ratio of 45 to 1 causes the pellet to accelerate from 10 m/s at the entrance to about 35 m/s at the exit. The orifice is mounted in a plate that has two degrees of movement for orifice alignment. The liquid pellet freezes[5] from surface evaporation within a few hundred mm of flight in the high vacuum after it goes through the orifice.

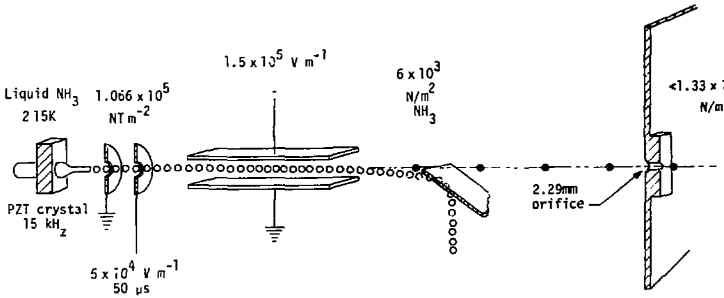

Fig. 5. Ammonia pellet charging and deflection scheme.

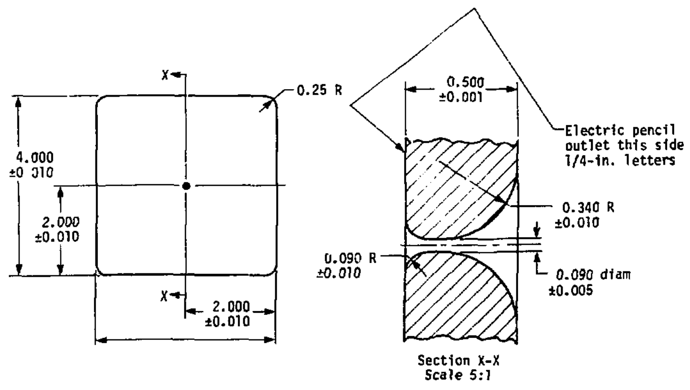

Fig. 6. Orifice plate.

Vacuum Pumping System

The main requirement for ammonia gas pumping is that the vacuum pumps and gas handling equipment cannot have any copper, brass, or bronze parts. We found that Kepton would deteriorate in the NH_3 atmosphere while polyvinyl chloride and silastic would not. We have successfully used combinations of pumping schemes, such as a liquid nitrogen condensing surface, a vane pump, a diffusion pump, a diffusion ejector pump, and a mechanical pump (as shown in Figure 7). The oil in the mechanical pump will break down and lose its lubricating qualities, and should therefore be changed quite frequently. Although water can dissolve ammonia gas, we tried this without satisfactory results.[10] There is a problem in handling large quantities of water. We are planning to try a liquid-ring vacuum pump, with water as the sealing fluid. Through-put of the vacuum system is only about 2 cfm, which will require only about 1 gpm of cooling water for sealing, and this small quantity should not impose much of a disposal problem.

Pellet Guidance and Delivery System

The pellet detection chamber (Fig. 2) has two quadrupole detectors spaced 60 cm apart. Pellet velocity and location with respect to the center line is computed from these detector signals. Pellet mass-to-charge ratio is also computed by the amount of pellet deflection from the neutral stream across a pair of horizontal plates that have a known applied electrical field. Knowing the velocity and mass-to-charge ratio, a final trajectory[11] correction is made by applying the proper electrical potential across the deflection plates in the BB II-T magnet chamber (Fig. 8). We have perfected the pellet guidance system to deliver one pellet per second through a 5-mm diameter pattern at the target zone. Because the pellet distribution is random, caused by

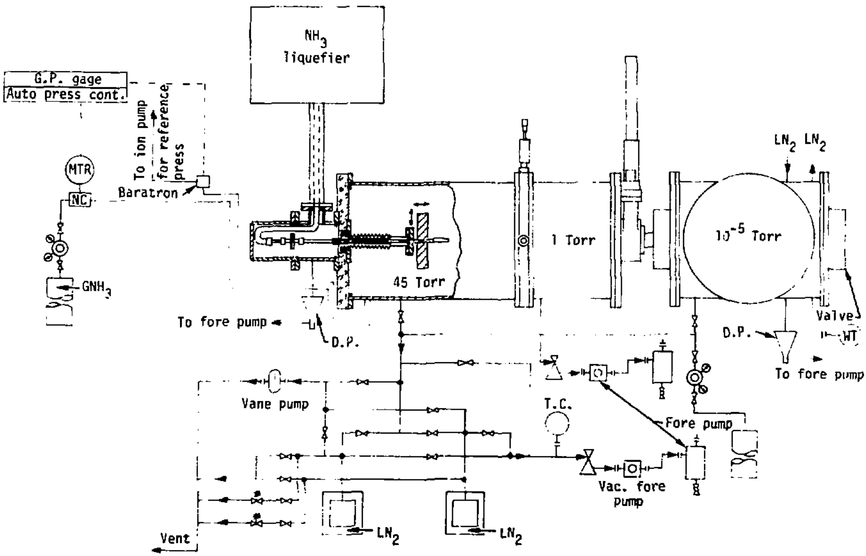

Fig. 7. Ammonia pellet generator primary vacuum pumping system.

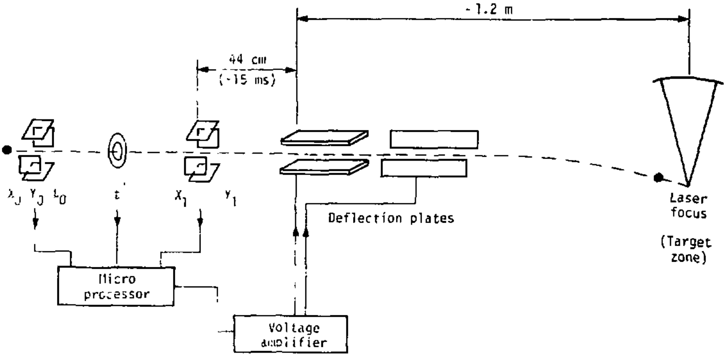

Fig. 8. Pellet guidance and delivery system.

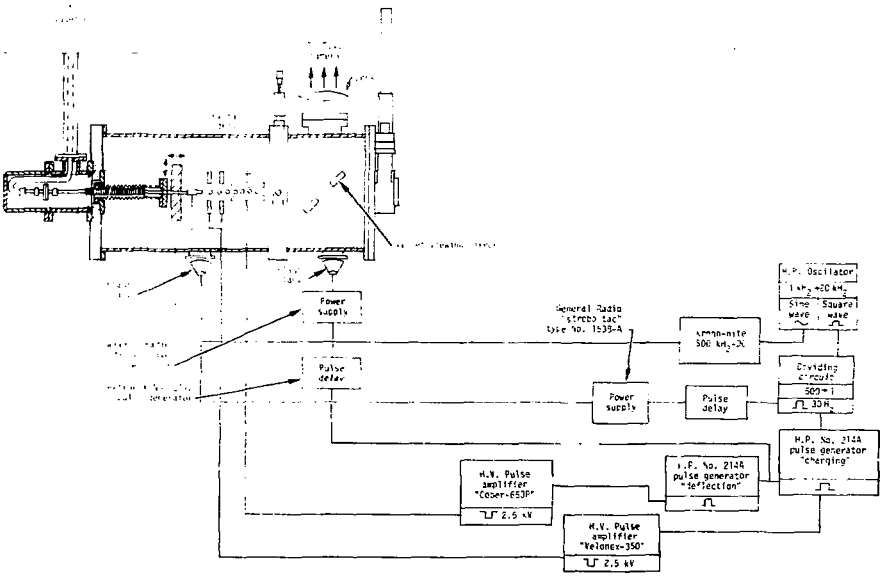

Fig 9. Ammonia pellet generator electrical system.

the disturbance introduced in the pellet velocity at the orifice, we compute that one pellet per minute passes through a 0.02-mm laser beam at the target. A schematic of electrical system is shown in Fig. 9.

Conclusion

A frozen ammonia micro-pellet generator has been developed to produce frozen ammonia pellets 40 to 200 μm in diameter at a rate of up to 18 000 per s. The pellets have been successfully frozen and accelerated up to 40 m s^{-1} velocities. We can separate the pellets by charging any given number of pellets out of a neutral stream. The mass-to-charge ratio has been measured to be about 10^{-3} C/kg. Pellet delivery systems were developed to deliver a frozen ammonia pellet from the pellet gun into a 0.2-mm diameter focal zone 3 m away.

Acknowledgments

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