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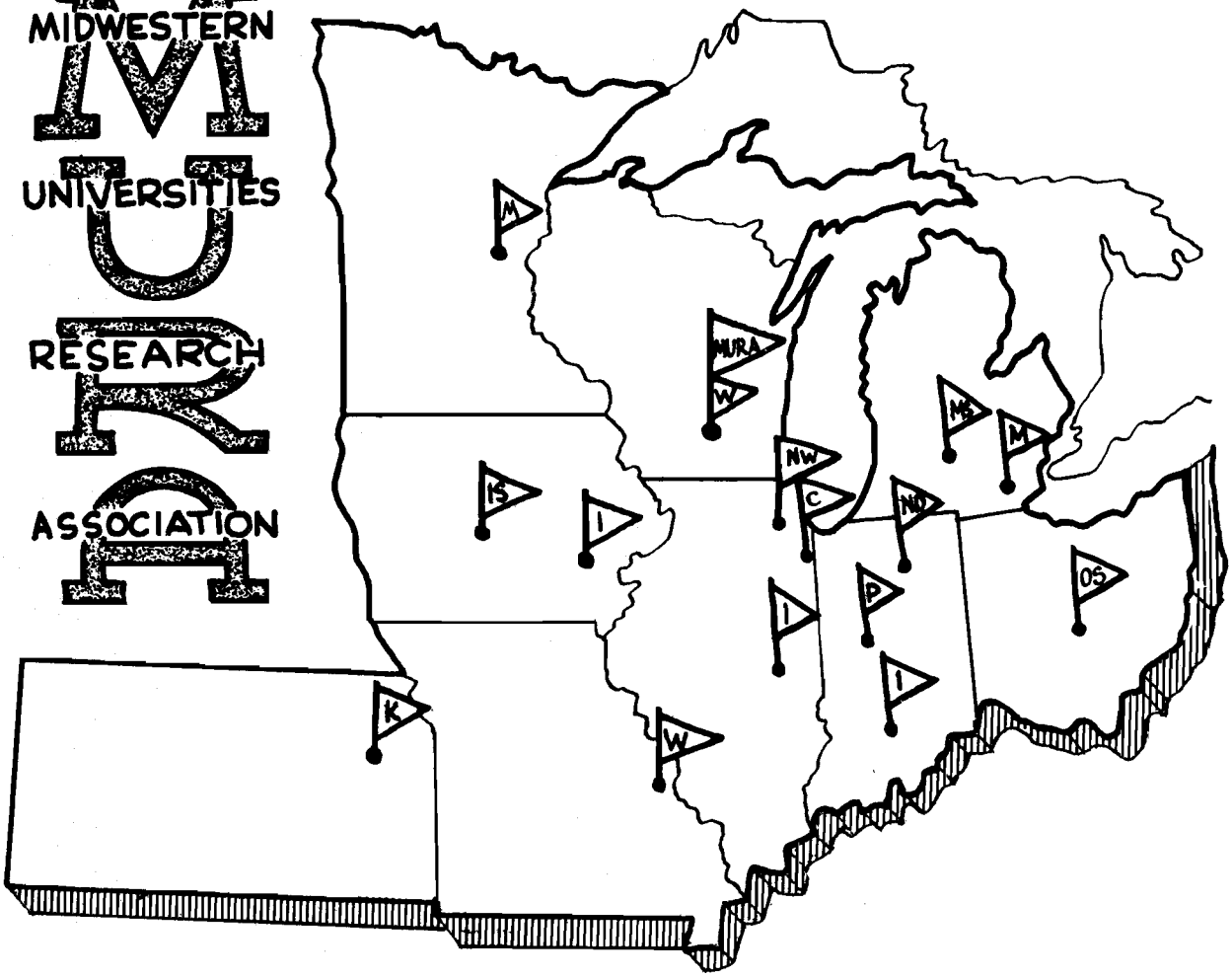

A SPECULATION ON A METHOD OF PROPULSION BY ION THRUST

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A SPECULATION ON A METHOD OF PROPULSION BY ION THRUST

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ABSTRACT: An amateurish method of obtaining ion thrust by using the drift of a plasma in a magnetic field similar to the adiabatic expansion of gases is discussed. The method is also applicable to ion vacuum pumps. An interesting feature of the engine is that it can be driven directly by thermonuclear reactor.

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** On leave from University of Tokyo

When the valve of a container of a high pressure gas is opened, the outcoming gas would cool itself and give a thrust to the container. From a microscopic point of view, the thermal velocities of the gas molecules are converted to ordered velocities by a sudden removal of the pressure.

The thrust is given by the product of the pressure and the cross-section of the outlet and it does not matter whether the high pressure is made by high density or high temperature.

To apply this method to an ion thrust jet, a magnetic field can be a container and a plasma a gas. The axial magnetic field is decreasing in the direction of the exhaust as shown in Fig. 1. Air is led through the intake to the region of strong magnetic field without suffering any effects of the magnetic field. Then an electric discharge might be produced there. The discharge should not be produced along magnetic field lines, so that the ions have components of velocities perpendicular to the field. It might be an r-f discharge using an r-f coil which has the same axis as the magnetic field and produces an electric field perpendicular to the magentic field. The plasma would proceed towards the lower field (lower pressure) region due to the force exerted on a plasma in a non-uniform magnetic field or microscopically conversion of the perpendicular components of the velocities of ions into parallel components.[1]

The power comes from the electric power maintaining the discharge in a strong magnetic field. The gas can be preheated and ionized by a discharge along the magnetic field, if a rather low temperature is desired. In this case, the power comes from the heat.

[1]For example, L. Spitzer: Physics of Fully Ionized Gases.

The thrust depends on the product of the pressure and the effective cross-section of the engine and we have a choice whether to use a high density, low temperature gas or a low density, high temperature gas.

Since it takes of the order of electron volts to ionize a gas molecule, the efficiency of the engine is quite low unless a high temperature of several electron volts is used. Therefore we are bound to use a low density high temperature plasma to get reasonable efficiency.

At any rate, the obtainable thrust is determined by the magnitude (pressure) of the magnetic field. For example, a magnetic field of 10000 gausses is equivalent to about four atmospheres pressure and can give about nine pounds per square centimeter thrust.

An ion density of the plasma corresponding to about 1% of normal air and a temperature of the order of 10 ev might be used. The plasma exerts about 4 atomospheres pressure and can be held by a magnetic field of $\sim$10000 gausses. To produce such a plasma, the electric field should be of the order of 1000 v/cm.

An engine having an effective cross-section of 10^4 cm^2 would deliver $\sim 10^5$ pounds thrust.

The above method may be used as a vacuum pump. For a lower vacuum, a weak magnetic field might be used and a higher field for a higher vacuum to make discharge easier.

To dream further, the above engine can be combined directly with a thermonuclear fusion reactor. It has been well known that fusion reactions can be produced, if we can confine a hot ($\sim$10 kev) plasma. The so-called external field type pinch effect might be modified as follows, assuming a very high magnetic field can be achieved. Instead of pulsing the magnetic field and using the inter-

action between H_z and i_θ resulted from E_θ, we might have a D. C. magnetic field (or pulsed, if preferred) and a plasma gun as shown in Fig. 2.

The plasma ejected from the gun will proceed into the stronger field region to be heated up by converting its kinetic energy (as a whole) into a form of temperature. This is similar to the $H_z - i_\theta$ pinch effect. If we achieve a very strong magnetic field; say 10^5 gausses, thermonuclear reaction would take place in the plasma. Fortunately this happens in a strong magnetic field and can be directly combined with the engine.

Air can be led into the reaction region and heated up and ionized by nuclear reaction heat. Therefore there is produced a moderately hot plasma in a strong magnetic field.

An imaginary picture of the system is shown in Fig. 3.

Fig. 1

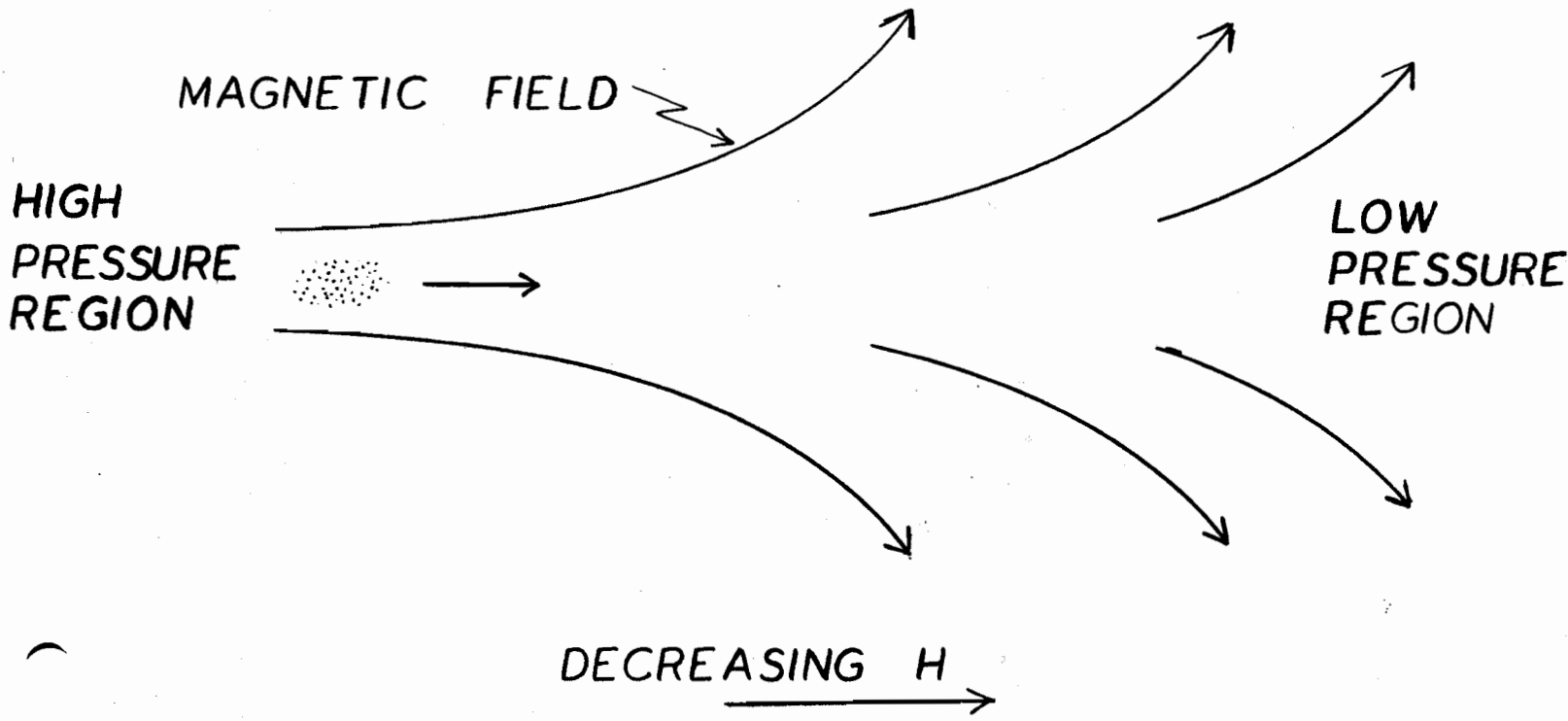
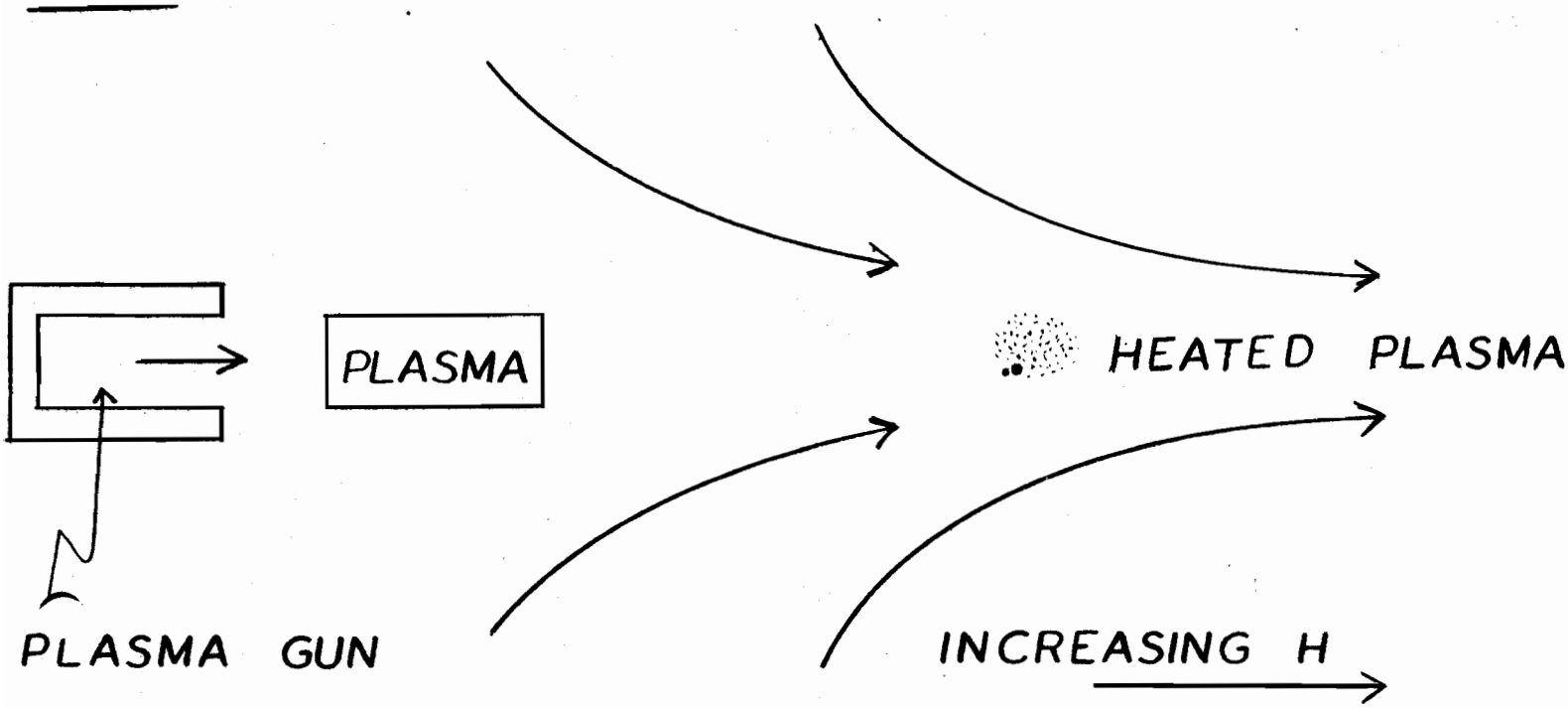

MAGNETIC FIELD
HIGH PRESSURE REGION
LOW PRESSURE REGION
DECREASING H

Fig. 2


PLASMA
HEATED PLASMA
PLASMA GUN
INCREASING H

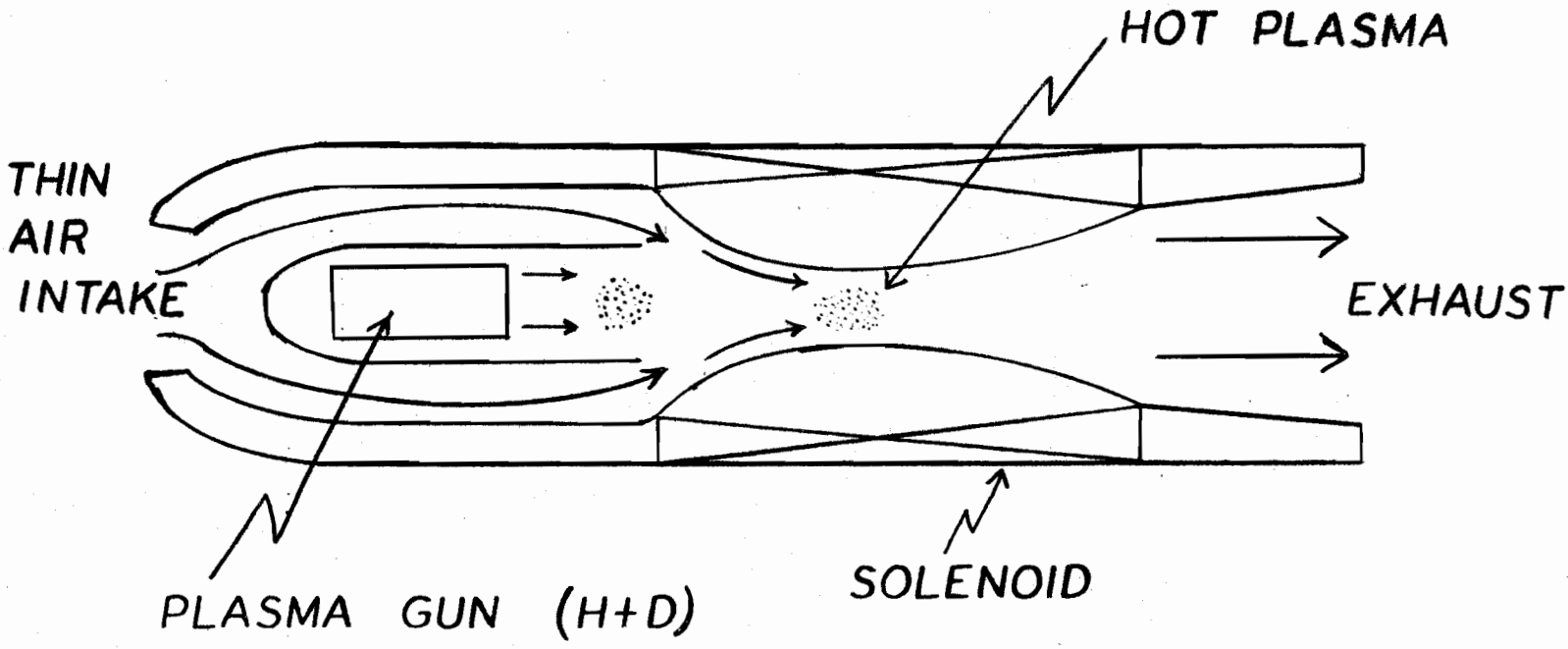


Fig. 3