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PARTICLE PARAMETER SELECTION SYSTEM FOR AN ELECTROSTATIC PARTICLE ACCELERATOR

by J. F. Friichtenicht

Prepared under Contract No. NASw-936 *by*
TRW SPACE TECHNOLOGY LABORATORIES
Redondo Beach, Calif.
for

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PARTICLE PARAMETER SELECTION SYSTEM FOR AN ELECTROSTATIC PARTICLE ACCELERATOR*

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INTRODUCTION

The electrostatic hypervelocity particle accelerator[1] has been used in a variety of experiments concerned with micrometeoroid simulation and hypervelocity impact.[2] One of the major problems associated with the use of the accelerator is the inability to specify in advance the parameters of a particle prior to impact upon an experimental complex. This occurs because of the size distribution of particles comprising the particle supply. As has been shown,[3] the charge-to-mass ratio (and therefore, the final velocity) is an inverse function of particle size. The iron powder which has been used extensively contains particles ranging from a few tenths to several microns in diameter. Thus, wide variations in particle velocity and mass are observed.

The use of finely graded powders in several size ranges would partially alleviate the problem. Unfortunately, the state of fine particle technology has not advanced to the point of providing suitable particles. An alternative method is to make the particle selection following acceleration and prior to impact.

Since the particle charge-to-mass ratio is a function of particle size, specification of particle velocity also specifies particle size to an accuracy determined by variations in the charging process. A system which permits particles with velocities within a small interval to reach the target while rejecting all others is a satisfactory solution to the data collection problem. A system embodying this concept has been constructed and tested.

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The main elements of this system are an electrostatic deflector, a velocity sensing and gating circuit, and a high voltage pulse circuit. Each of these elements are discussed below.

The Electrostatic Deflector

The function of the electrostatic deflector is to deflect unwanted particles from the beam while permitting selected particles to pass through unperturbed. The deflector, consisting of a pair of parallel plates with a potential difference V_d between them, is shown schematically in Fig. 1. Upon entering the region between the plates, particles from the accelerator experience a force perpendicular to the original direction of motion given by

$$F_p = qE \quad , \tag{1}$$

where q is the particle charge and E is the electric field between the plates. Integrating, we get

$$v_p = \frac{q}{m}Et \quad , \tag{2}$$

where v_p is the velocity component perpendicular to the original trajectory, m is the particle mass, and t is the time spent in the deflection region. The time required to traverse the length of the plates L is determined by the initial velocity v and is given by

$$t = \frac{L}{v} = L \left(\frac{m}{2qV}\right)^{1/2} \quad , \tag{3}$$

where V is the accelerating voltage. The perpendicular velocity component at the exit plane of the plates is

$$v_p = E \left(\frac{m}{2qV}\right)^{1/2} L \quad . \tag{4}$$

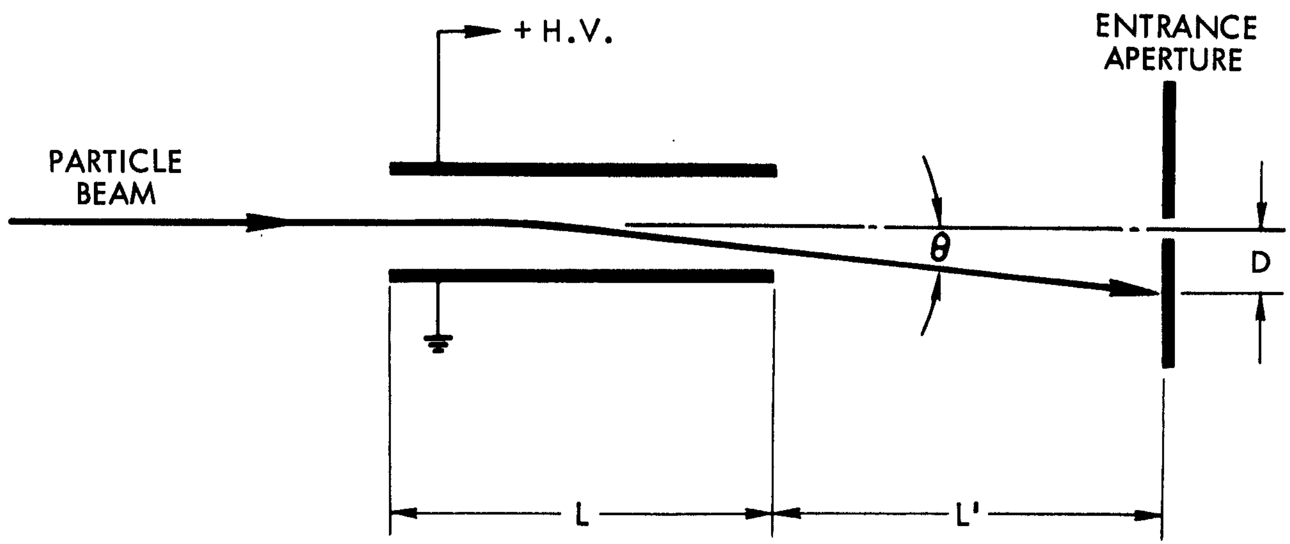

Figure 1. Sketch depicting the operation of the electrostatic deflector.

Furthermore,

$$\frac{v_p}{v} = \frac{EL}{2V} \tan \theta \quad , \tag{5}$$

where θ is the angle between the initial and final trajectories. It should be noted that this expression is independent of particle parameters and all particles traversing the deflection region describe identical trajectories regardless of their charge-to-mass ratio.

By integrating Eq. (2) and combining the result with Eq. (5), it is a simple matter to determine the total displacement D imparted to the particle at any distance L' downstream from the particle deflector. For values of $E = 2 \times 10^6$ volts/meter, $V = 2 \times 10^6$ volts, L = 0.15 meter, and L' = 0.15 meter, the displacement is 1.25 cm. Since particles from the accelerator are focused into a much smaller spot than this, the magnitude of the deflection is more than adequate to deflect particles from the entrance aperture of an experimental chamber.

The Velocity Sensing and Gate Circuit

As was mentioned above, specifying particle velocity determines particle mass for a given set of conditions. Accordingly, particle parameter selection is made on the basis of a velocity measurement. The velocity selection system is illustrated schematically in Fig. 2. The velocity sensor consists of a pair of short, capacitive-type detectors (see Ref. 3) separated by a fixed distance. The signals from each of the detectors are amplified and presented to voltage discriminators where uniform pulses are generated for each signal exceeding the discrimination level. The output pulse from the first discriminator triggers a "one-shot" multivibrator which produces a pulse of adjustable length. The trailing edge of this pulse triggers another one-shot multivibrator of variable, but preset length. This pulse opens the

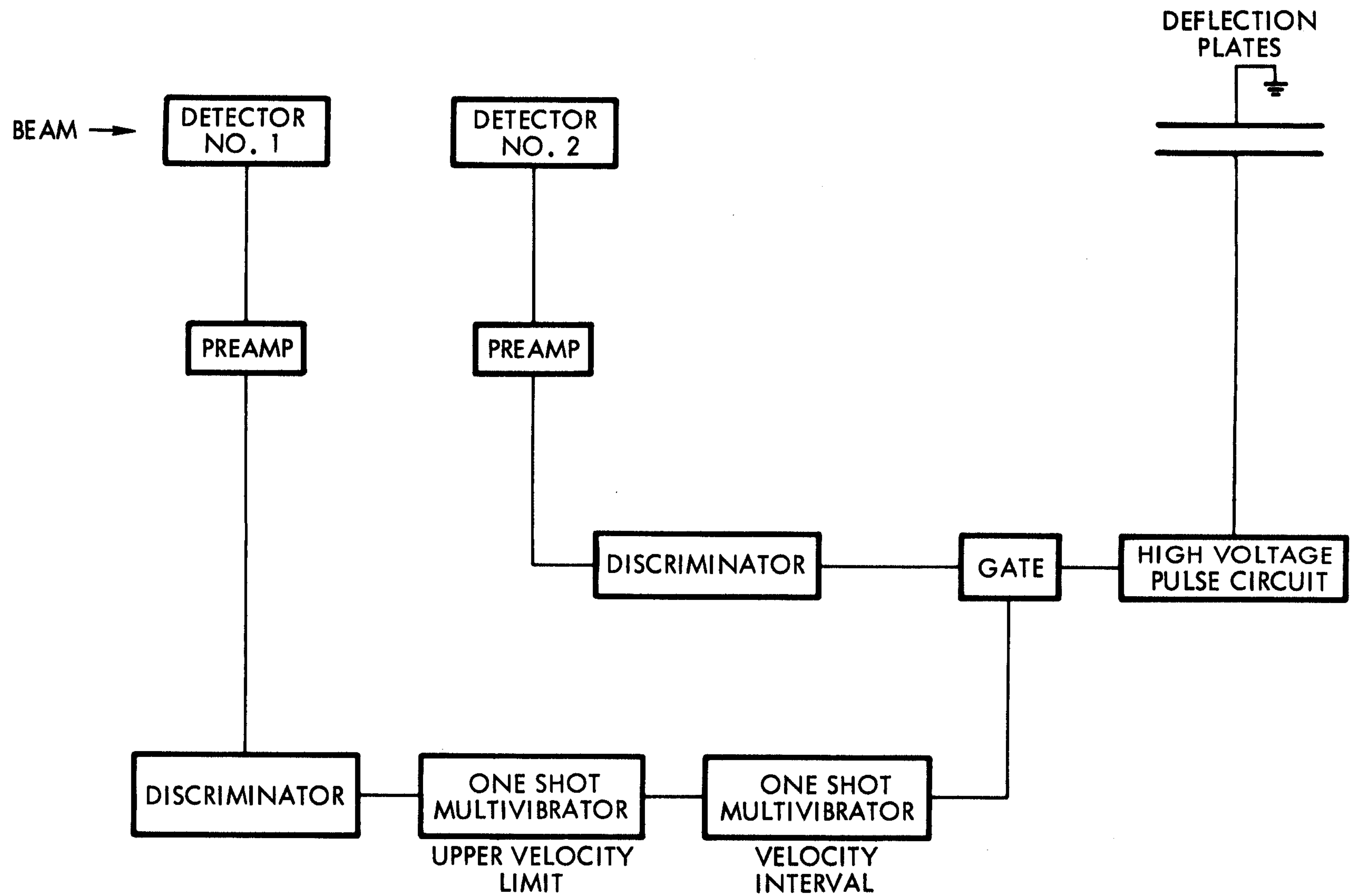

Figure 2. Block diagram of the particle parameter selection system.

gate of an electronic gating circuit for the duration of the pulse. The output pulse from the second discriminator is fed to the gate and if it appears while the gate is open, an output trigger pulse is generated. The trigger pulse is delivered to the high voltage section of the system.

It can be seen that the duration of the first multivibrator pulse determines the upper velocity limit of the system while the duration of the second multivibrator pulse determines the velocity interval over which trigger pulses are generated. The durations of both of these pulses are adjusted by switching the multivibrator coupling capacitors. The switching is accomplished by multi-position wafer switches and a wide variety of velocity intervals may be selected.

It should be pointed out that the velocity sensing system can be used to advantage in other ways, as well. For example, the trigger pulse can be used to gate an oscilloscope in order to display only desired signals, while ignoring all others. The use of the system also increases the apparent signal-to-noise ratio of the detectors. The latter manifestation is discussed more thoroughly in another report[4] which also includes a detailed description of the electronic circuitry.

The High Voltage Pulse Section

When a trigger pulse is received, the high voltage pulse circuit discharges the voltage across the deflection plates, thereby allowing the particle to proceed on to the target. With the exception of the method by which the grid drive pulse is generated,[5] the operation of the high voltage pulse circuit is conventional in all respects.

The trigger pulse from the velocity sensing and gate circuit is first fed to a one-shot multivibrator whose period is adjustable to several values roughly corresponding to the time required for the selected particle to traverse the deflection region. The output pulse from the multivibrator is applied to the grid drive pulse generator. This circuit produces a moderately fast rising high voltage pulse (about 1,000 volts negative) of a duration equal to the length of the input pulse. For a detailed description of the grid drive pulse generator which employs all solid-state electronics, see Ref. 5.

One plate of the deflection system is grounded while the other is connected to the plate of a high voltage pulse modulator tube. Normally the tube is cut off and the deflection plate is at the power supply voltage. Application of the driver pulse to the grid via an inverting 1:1 pulse transformer drives the tube into saturation thereby dropping the voltage between the deflection plates.

For proper operation of the deflector, the voltage between the plates must be completely discharged before the particle arrives and must remain discharged until the particle has traversed the plates. These requirements impose limits upon the rise time and duration of the high voltage pulse. The deflection plates constitute a capacitive load for the tube of the order of 100 picofarads which must be discharged in about a microsecond. A high voltage pulse modulator tube (English Electric Valve Co., C1150/1, equivalent to an Eimac 4PR60B) was used in this case because of availability, although somewhat lower power tubes would be equally satisfactory.

SUMMARY

The particle parameter selection system described above is a valuable addition to the techniques and methods which have been developed in connection with the electrostatic particle accelerator. Even when used alone, the velocity sensing and gate circuit is very useful in the detection and measurement of very small high speed particles because of the noise reduction inherent in the system. The deflection system is most useful in cases where

it is desirable to protect the target from bombardment by particles possessing characteristics other than those within a given range. Also, certain types of experiments require extensive post-bombardment analysis, and the ability to preferentially select certain parameters in advance would reduce the time spent in the analysis of redundant or unnecessary data.

In the present system, the selection mechanism is based strictly on a velocity measurement. This determines particle mass to an accuracy determined by variations in the charging mechanism. If such variations are excessive, the system can be modified to eliminate them. This can be accomplished by adding the requirement that the signal amplitude lie within some small interval. This is equivalent to specifying a charge interval. The simultaneous specification of particle charge and velocity is sufficient to specify particle mass for a given accelerating voltage. Although this refinement has not been included in the present system, it is clear that addition of this feature is a straightforward process.

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