4158-6016-TU-000

TECHNICAL REPORT

"ELECTRONIC PARTICLE-PARAMETER ANALYZING SYSTEM FOR AN ELECTROSTATIC HYPERVELOCITY PROJECTOR"

July 1965

N66-15596 (ACCESSION NUMBER)
14 (PAGES)
CR 69446 (NASA CR OR TMX OR AD NUMBER)
(THRU) 1 (CODE) 11 (CATEGORY)
FACILITY FORM 602

Prepared for

National Aeronautics and Space Administration
Washington, D. C. 20546

Contract No. NASw-936

Prepared by
D. O. Hansen

Approved by
J. F. Friichtenicht
Manager, Meteoritics Dept.

PHYSICAL ELECTRONICS LABORATORY
Physical Research Division

TRW Systems
One Space Park, Redondo Beach, California

ELECTRONIC PARTICLE-PARAMETER ANALYZING SYSTEM FOR AN ELECTROSTATIC HYPERVELOCITY PROJECTOR

I. INTRODUCTION

Refinements of equipment and techniques used with the TRW electrostatic hypervelocity accelerator[1] have enhanced its performance and increased its versatility. Detector preamplifiers have been improved to the point that much higher-velocity particles may be detected. In addition, a high-repetition-rate particle injection system has been developed for use in experiments requiring a large particle flux.

One complication that has arisen from improved accelerator performance is that the increasing rate of data acquisition has necessitated more complex computational procedures than those originally used. In general, particle parameters are determined from arithmetical computations involving the amplitude and duration of the detector signal and other system variables. Although the calculations are straightforward, they are time consuming, and this method is not practical for large volumes of data. This problem has led to the development of an automatic particle parameter analyzing system described below.

II. ELECTRONIC X-Y PLOTTER

The main component of the system that has been developed for automatic particle-parameter analysis is an electronic X-Y plotter. In this system each particle is represented by a point on a two-dimensional display. The displacement of the point along the Y axis is proportional to the charge on the particle, and the displacement in the X direction is proportional to its transit time through the detector. Since each particle is represented by a single point, rather than by a rectangular pulse as in the former method, a large number of data points can be placed on a single display before confusion arises. As will be shown later, lines of equal radius and velocity can be drawn on the plot and will form a number of irregularly shaped areas, each of which correspond to a specific velocity and radius range. The radius and velocity of each particle can be determined fairly accurately by simply observing into which area the point falls.

A simplified block diagram of the X-Y plotter circuit is shown in Fig. 1. The pulse from the particle detector is fed to three separate circuits - a pulse stretcher, discriminator, and differentiating circuit. The pulse stretcher produces a pulse that has the same amplitude but is much longer than the input pulse. The stretched pulse is applied to the vertical amplifier of an oscilloscope and deflects the beam vertically by an amount equal to the original pulse height. The oscilloscope sweep is triggered when the detector pulse exceeds the threshold imposed by the discriminator. The negative pulse from the differentiating network, which occurs at the trailing edge of the detector pulse, is fed to the oscilloscope brightener-pulse generator. The brightener-pulse generator delivers a short-duration, rectangular voltage pulse to the cathode of the oscilloscope. In operation, the beam intensity control of the oscilloscope is adjusted so that the trace is visible only when the brightening pulse is applied to the cathode. Since brightening occurs at the trailing edge of the pulse, and at the same time the vertical displacement is proportional to detector pulse height, the position of the brightened spot gives the desired information.

A further refinement makes provision for the display of information regarding the effect of particle impact after the particle has passed through the detector. Generally this feature is restricted to a simple "yes-no" type of response. The mechanism for implementing this response is shown in Fig. 2. The stretched pulse is applied to the vertical input of the oscilloscope as before, but the output pulses from the differentiating network

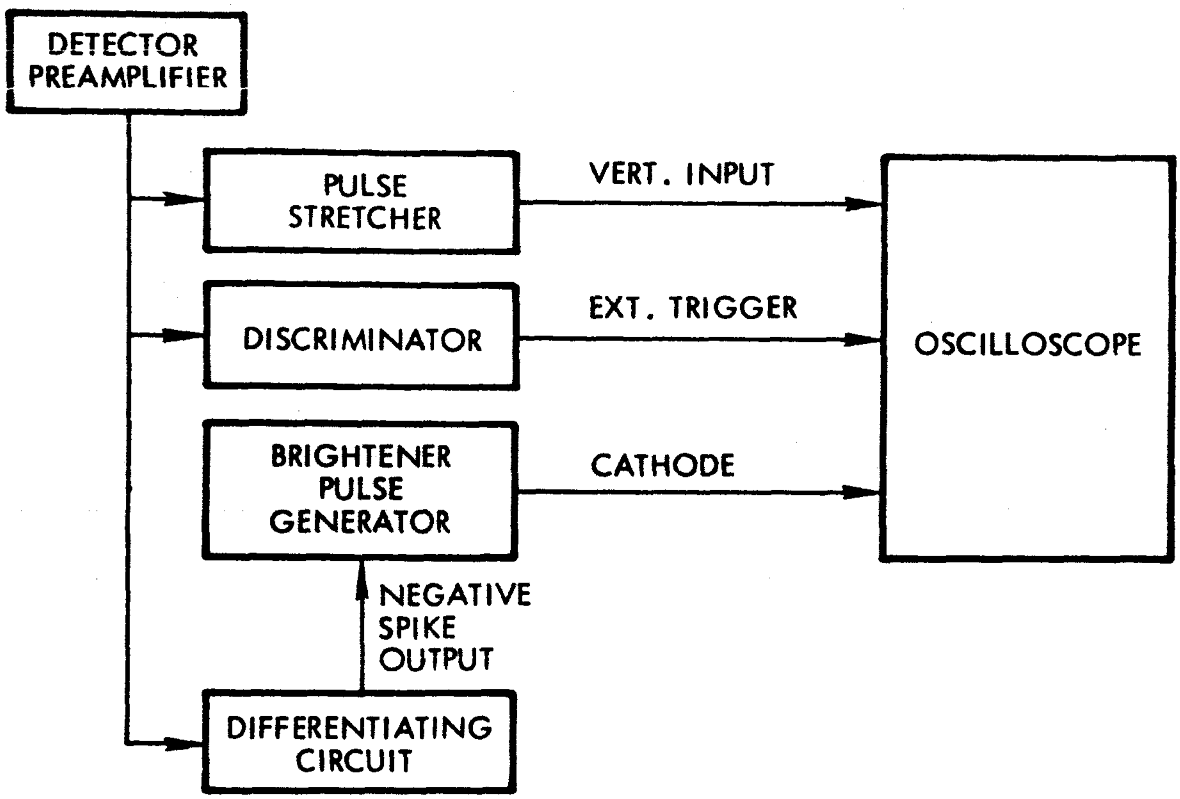

Figure 1. Simplified Block Diagram of the Basic X-Y Plotter

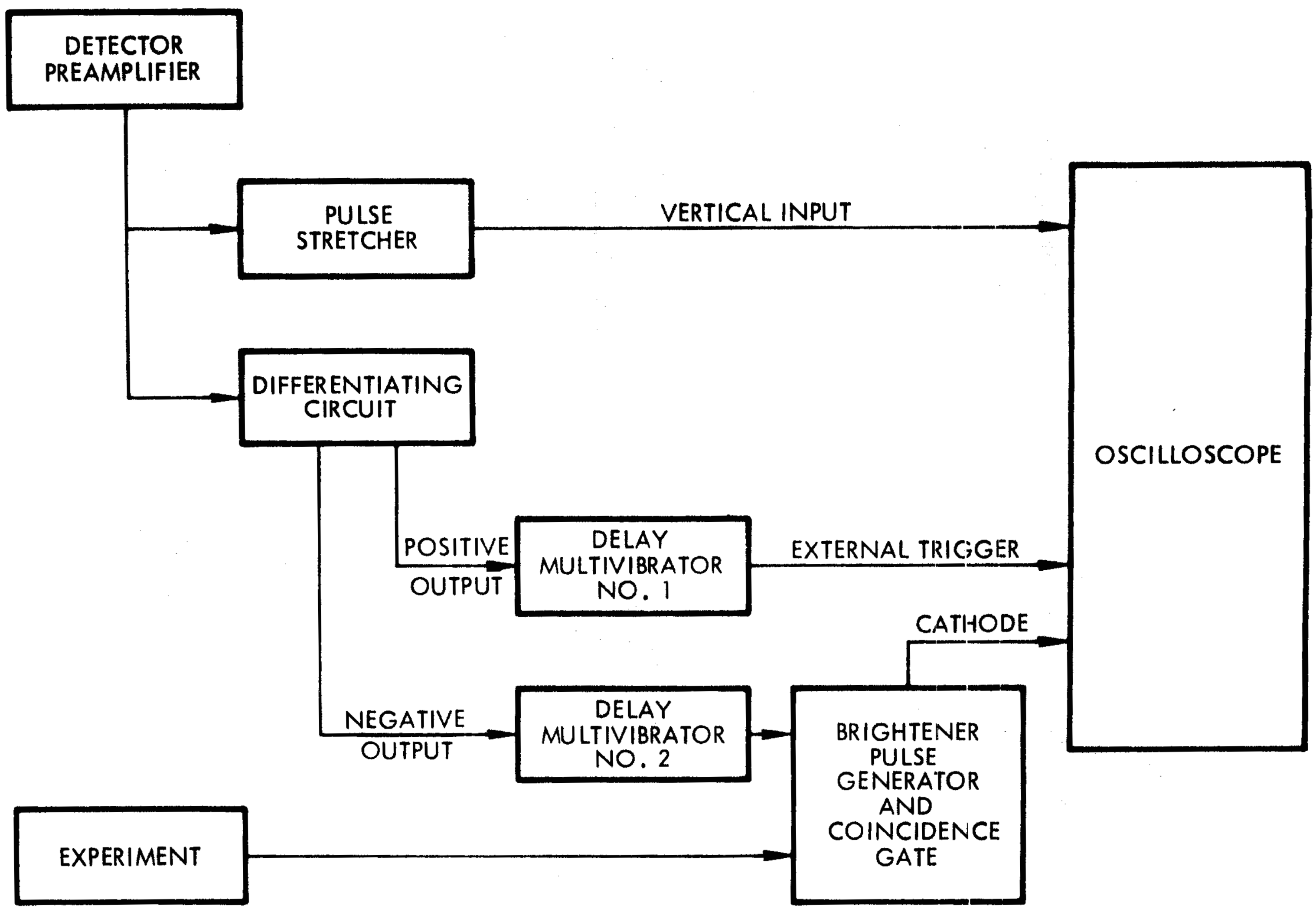

Figure 2. Block Diagram of the X-Y Plotter including the "yes-no" feature. In this application the output signal from the experiment must be characterized by a two-state response.

are applied to two 100-μsec duration delay multivibrators. The first of these is triggered by the positive spike corresponding to the leading edge of the detector pulse while the second is triggered by the negative spike which occurs at the trailing edge of the detector signal. The trailing edge of the output pulse from the first multivibrator is used to trigger the horizontal sweep of the oscilloscope. The differentiated pulse from the second multivibrator is fed to the oscilloscope trace brightener unit. If no further input is provided to the trace-brightener, the trace is brightened in exactly the same manner as described above except that it is delayed by 100 μsec.

The "yes-no" feature is characterized by changing the duration of the trace-brightener pulse. The electrical signal from the experiment in question is applied to an electronic gate and, if it appears in the time interval specified by the duration of the delay multivibrators, the output pulse from the trace-brightener is several times longer. This results in points being plotted for "no" events and short lines being recorded for "yes" events. The analysis of particle parameters is the same in either case. This feature has been particularly useful in experiments which have been conducted on the initiation of voltage breakdown by particle impacts.[2]

III. PARTICLE-PARAMETER ANALYSIS WITH THE X-Y PLOTTER

The amplitude of a detector signal (or the displacement of a point along the Y axis when using the X-Y plotter) is given by

$$V_o = \frac{qG}{C_d} \quad , \tag{1}$$

where V_o is the signal amplitude in volts, q is the particle charge, C_d is the capacitance of the detector, and G is the voltage gain of the preamplifier. Defining $V_o = yS_v$, where y is the amplitude in scale divisions and S_v is the sensitivity of the oscilloscope in volts/scale division, we get

$$q = y\left[\frac{S_v C_d}{G}\right] \quad . \tag{2}$$

Similarly, the duration of the signal (or X displacement is the transit time τ through a detector of known length L. From this we get

$$v = \frac{L}{\tau} = \frac{L}{xS_s} \quad , \tag{3}$$

where x is the signal length in scale divisions and S_s is the sweep sensitivity in seconds/scale division. Substituting into the conservation of energy equation,

$$1/2\ mv^2 = qV_a \quad , \tag{4}$$

where m is the particle mass and V_a the accelerating voltage, and rearranging, we get

$$m = \left[\frac{2S_v S_s^{\ 2}\ C_d V_a}{GL^2}\right] yx^2 \quad . \tag{5}$$

For spherical particles of density ρ, the radius r is obtained from

$$r^3 = \left[\frac{3S_v S_s^{\ 2}\ C_d V_a}{2\pi\rho GL^2}\right] yx^2 \quad . \tag{6}$$

For any given experiment the quantities in brackets are constant and are known. Thus we can write

$$\frac{r^3}{K} = yx^2 \quad . \tag{7}$$

Given the X and Y displacements of a given point, the radius of the particle represented by the point is determined uniquely for a specified value of K. Furthermore, lines of equal radius can be specified by plotting curves of yx^2 = a constant.

To avoid the problem of generating and plotting new sets of curves each time K is changed, we introduce two new quantities - namely, a parametric radius R and an arbitrary constant K_1 such that

$$\frac{R^3}{K_1} = yx^2 \quad . \tag{8}$$

By choosing an arbitrary value of K_1 and letting R take on different values, we can plot a family of equal-R curves. From Eqs. (7) and (8) we see that

$$\frac{R^3}{K_1} = \frac{r^3}{K}, \text{ or } r = \left[\frac{K}{K_1}\right]^{1/3} R \quad . \tag{9}$$

The curves generated for R are universal. Once a specified value for K is determined, the equal-R curves may be relabeled by use of Eq. (9).

This procedure is illustrated in Fig. 3. First a set of equal-R curves, with R taking values from 1 through 8 and K_1 = 5, were plotted. Then the data points recorded from a typical oscilloscope photograph were plotted on the same graph. For this run $K = 2.84 \times 10^{-20}$. From Eq. (9), r was determined to be 0.178R microns. The appropriate labels are shown in the figure.

It should be recognized, also, that the displacement of a point in the X direction is proportional to reciprocal velocity. Hence the velocity and radius of a particular particle can be determined to some degree of accuracy by inspection. The radius of a particle can be determined more accurately by interpolation along a line from the origin to the point. Substituting the

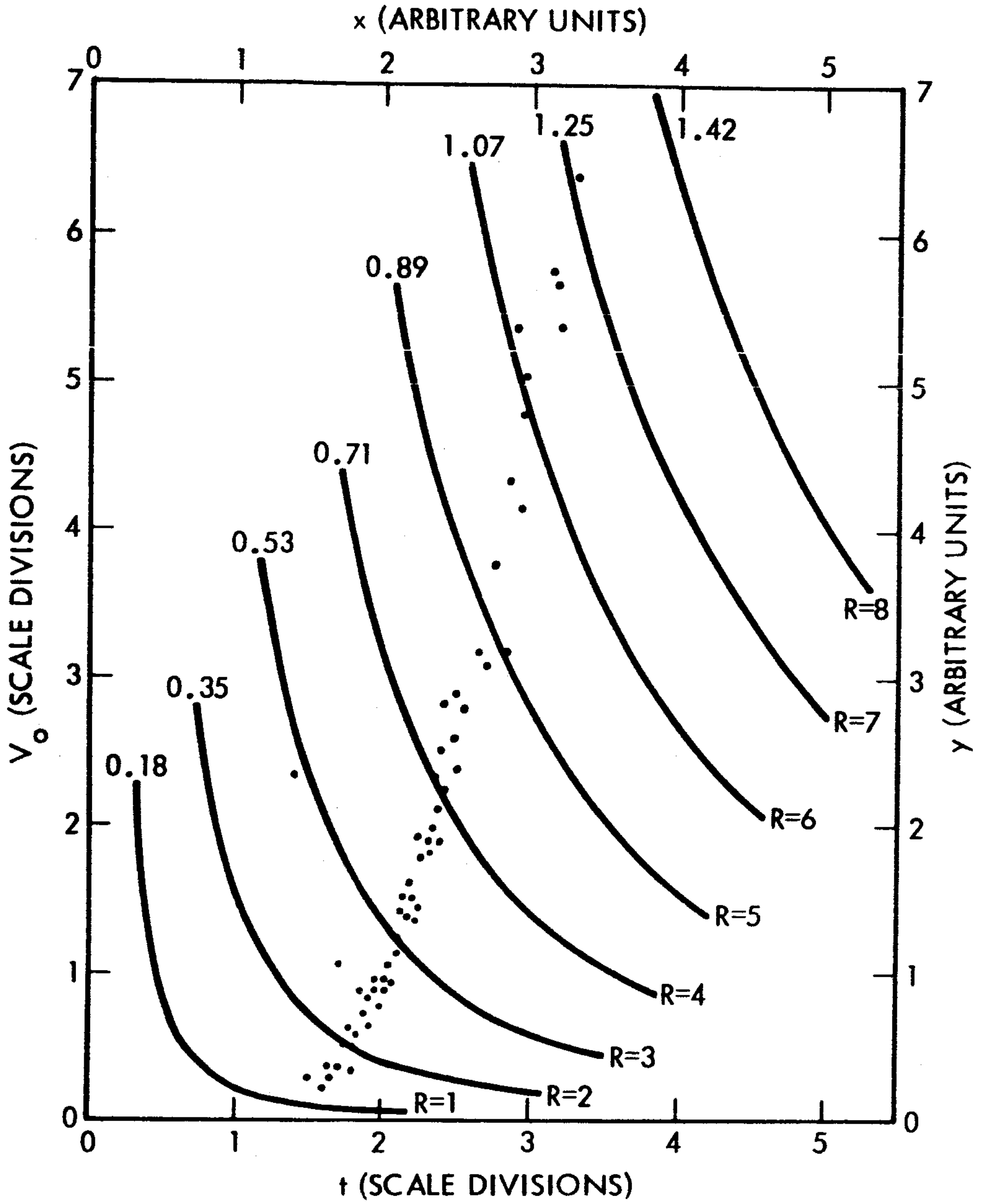

Figure 3. Example of Particle Parameter Analysis using the X-Y Plotter. The Equal R Curves were generated from $R^3 = 5 x y^2$. The data points were transferred from a photographic record of a typical run. The actual particle radius in microns represented by each R curve is noted at the left-hand terminus of each R curve.

equation of such a line, y = Cx, into Eq. (7) yields $r = x(CK)^{1/3}$. Thus measurement of the slope C and the X displacement yields r precisely.

To facilitate measurements, an oscilloscope graticule with equal-R curves etched on it has been prepared. Since the data may be read directly from the photograph, the necessity of transposing the data points has been eliminated.

vw

REFERENCES

1. J. F. Friichtenicht, Rev. of Sci. Instr., Vol. 33, p. 209 (1962).

2. J. F. Slattery, J. F. Friichtenicht and D. O. Hansen, Appl. Phys. Letters, Vol. 7, No. 1, p. 23, July, 1965.