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NOTE ON A METHOD OF ACCELERATOR ALIGNMENT USING A STRETCHED WIRE TECHNIQUE

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The stretched wire provides a well known method of establishing the alignment of an array of points. The application of this technique to the horizontal plane is obvious; application to the vertical plane requires corrections for the sag of the wire and for the curvature of the earth.

The vertical deviation of a wire from the straight line connecting its end points is given by:[1]

$$y = \frac{m}{2T}\left(z^2 - Lz\right) \qquad (1)$$

where m = mass of wire per unit length (lbs/ft.)
T = tension of wire (lbs.)
z = distance from fixed end to point of measurement (ft.)
L = distance between fixed ends of wire (ft.)

The maximum deviation will occur at $z = {}^{L}/_{2}$ at which point we obtain

$$y_{max} = -\frac{mL^2}{8T} \qquad (2)$$

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1 The correct "horizontal earth" equation for this case is that of the catenary but for relatively "flat" trajectories, the above equation of the parabola is quite accurate and is easier to handle. In any exact formulation, the curvature of the earth must be taken into account.

To keep the vertical deviation as small as possible for a given span L, it is necessary to choose the wire material, its diameter, and the tension T to minimize the ratio $^m/_T$. Thus, m should be as small and T as large as possible. A material of high tensile strength such as piano wire should be used. If the ultimate tensile strength in pounds per square inch were independent of wire diameter, the quantity $^m/_{T_{max}}$ would also be independent of diameter. However, the tensile strength (lbs./in.^{2}) increases slowly as the diameter decreases as shown in the following table. Thus, a small diameter wire is preferable in minimizing the deflection.

Strength of Piano Wire[1]

Size-Music Wire Gauge	Dia. (inches)	Ultimate Tensile Strength (lbs.)	Ultimate Tensile Strength (lbs./in.^{2})
12	.029	237	3.60×10^5
13	.031	268	3.55
14	.033	300	3.50
15	.035	322	3.45
16	.037	366	3.40
17	.039	400	3.35
18	.041	436	3.30

Consider, for example, the smallest wire size (.029" dia.) in the above table. With a specific gravity of 7.83, the piano wire steel weighs 490 lbs. per cubic foot so that a one-foot length of .029" dia. wire has a mass of 2.24×10^{-3} lbs. If the span is 10,000 feet and the maximum tension of 237 lbs. from the above table is used, we obtain from eq. (2):

$$y_{max} = -\frac{2.24 \times 10^{-3} \times 10^{8}}{8 \times 237} = -118 \text{ ft.}$$

This deflection is clearly too large for practical application of this method. If the span length L is reduced from 10,000 ft. to 1000 ft. the vertical deflection is reduced by a factor 100 so that $y_{max} = 1.18$ ft. For L = 250 Ft., y_{max} = .074 ft., etc.

Alignment in Horizontal Plane

To keep the vertical displacements to reasonable limits, consider the case where the total length to be aligned (10,000 ft.) is broken up into a number of equal sub-lengths (e.g., 250 ft. each). Polished support bars (Fig. 1) capable of vertical adjustment are provided at each intermediate support point and an adjustable plate with a hole slightly larger

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1 From pages 6-17, Kent's Mechanical Engineers' Handbook Eleventh Edition, Wiley Handbook Series

than the wire is provided at each end. One end of the wire is fixed; the other end passes over a low-friction pulley and is attached to a suspended weight. If the polished support bars were perfectly frictionless the wire would immediately take a position such that its vertical projection would define a straight line in a horizontal plane. Because of frictional effects at the bars, however, the alignment would not be perfect.

The effects of friction at the support bars can be removed in the following manner: starting at the fixed end of the wire, the first support bar is lowered until the wire is free of its surface. The wire will then move horizontally to take a position in line with the points of contact with the support bars on each side. This process is repeated with each support bar in sequence until all have been lowered and returned to position. The cycle is repeated as many times as necessary until the desired straightness is obtained over the entire length. This action can be accomplished either manually or by remotely controlled devices. The approach to straightness in successive approximations is illustrated in Fig. 2.

Alignment in Vertical Plane

To obtain alignment in the vertical plane, two parallel wires are threaded through the suspension points as shown in Fig. 3 and equal tension is applied to each. The wires are separated horizontally by a small distance (e.g., two or three wire thicknesses) to avoid contact. The problem of vertical alignment of the points $P_1 . . . P_{10}$ can be reduced to that of equalizing the deviations $y_1 . . . y_9$ between the reference points and the minima of the alternate wire. With observers at each reference point and telephone communication between these points and a central adjudicator, this trial and error procedure should be swiftly accomplished. Once the array of reference points is correctly established in space, the alignment of in-between points can be easily carried out by the stretched wire technique or by optical means. It should be noted that this procedure actually determines the locus of points along a curve concentric with the earth's surface. To obtain a straight line in the vertical plane, a vertical correction factor equal to $z^2/2\rho$ where z is the horizontal distance from the point of tangency to the earth's surface to the point of reference and ρ is the radius of the earth. At a distance of two miles, this correction factor amounts to 2.37 feet.

The techniques described above can be used to establish a straight line in space over the two mile accelerator length. For greatest accuracy of alignment in the vertical plane, the wire size and density should be as uniform as possible over the entire length. Air currents should be minimized, probably by locating the wire inside an evacuated tube provided with vertical and horizontal viewing ports.

Once a straight line is established in space, it should be a relatively simple matter to establish a parallel line defining the correct alignment of the accelerator axis.

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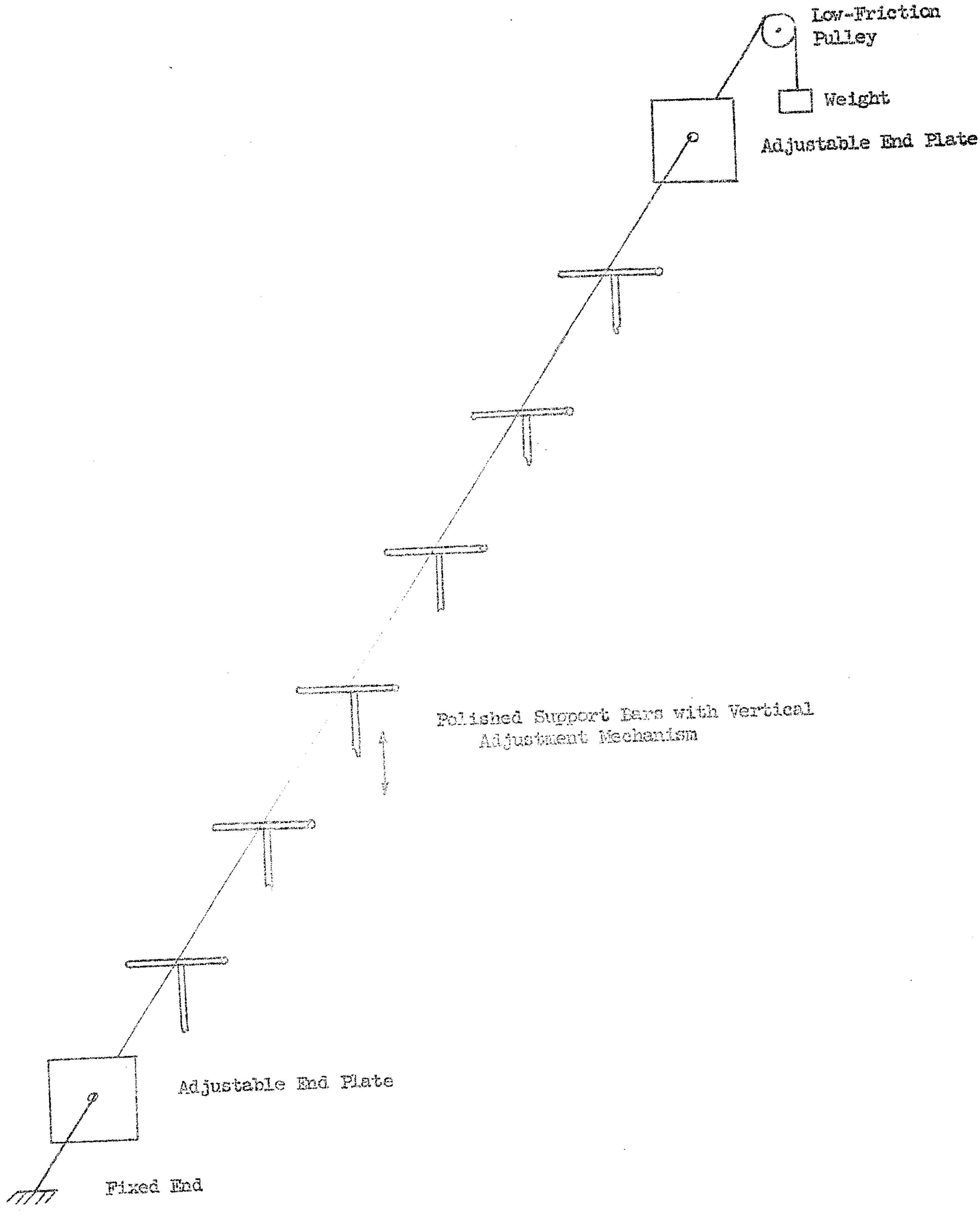
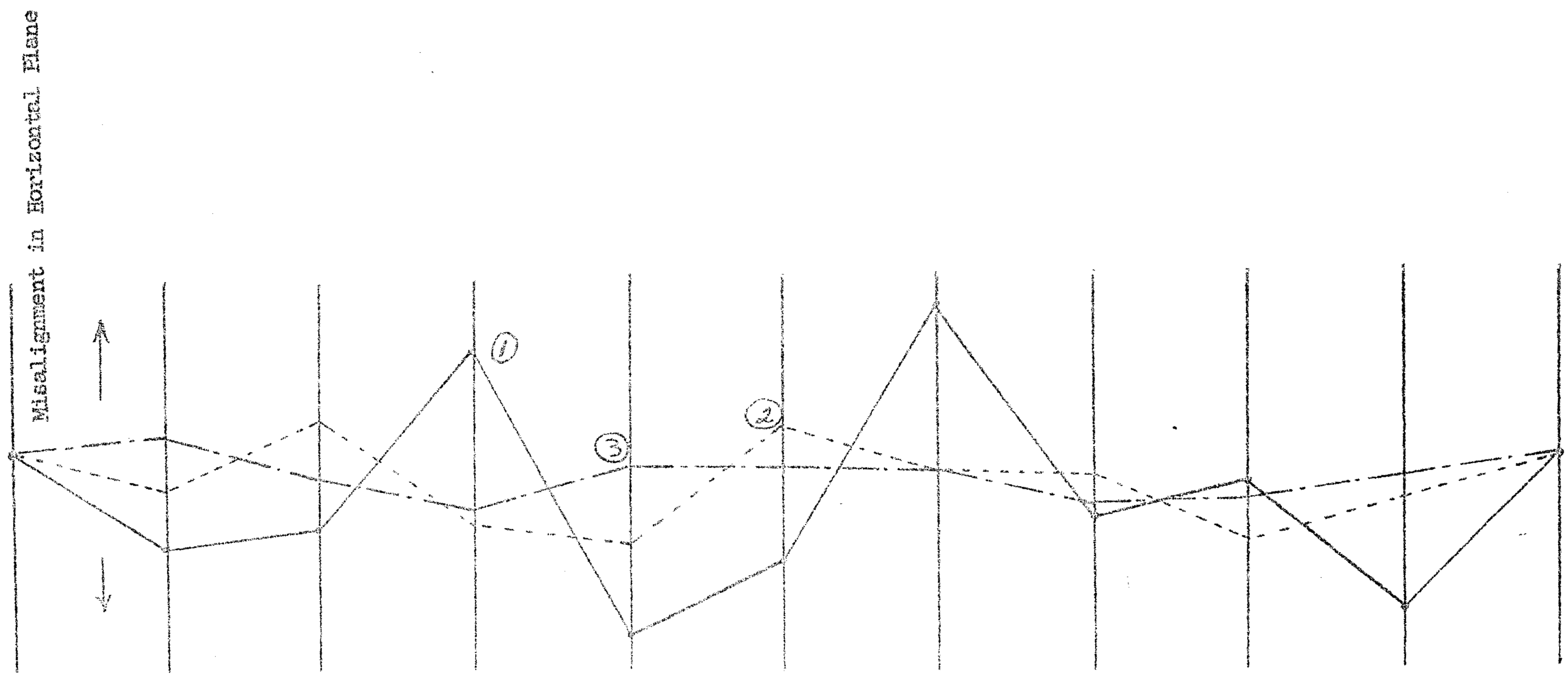


<u>Fig. 1</u> Schematic Diagram Illustrating Method of Obtaining Alignment in Horizontal Plane

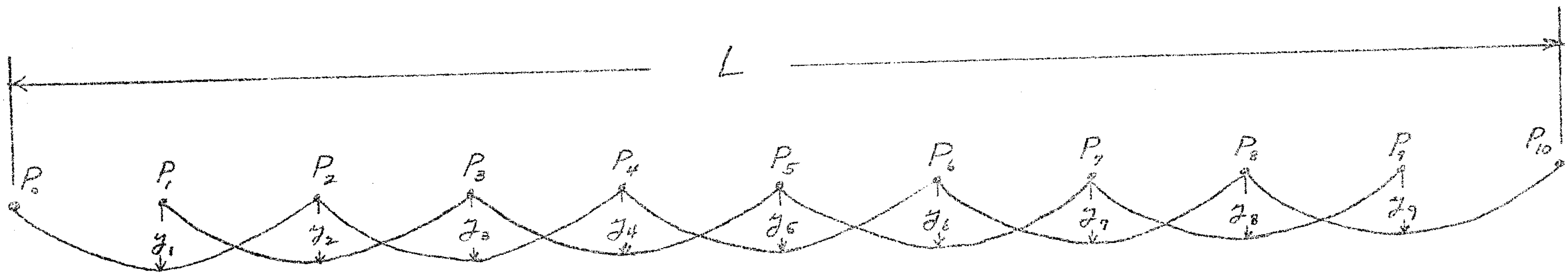


1 Assumed original path of wire

2 Path after one cycle of support bars

3 Path after two cycles of support bars

Fig. 2 Illustrating Successive Approximations to Straight Wire Obtained by Repeated Cycling in Vertical Position of Support Bars



Side View of Two Parallel Stretched Wires Having Equal Tension

Fig. 3 Schematic Diagram Illustrating Method of Obtaining Alignment in Vertical Plane