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FORCE-STRAIN CHARACTERISTICS AND RUPTURE-LOAD CAPABILITY OF VIKING-TYPE SUSPENSION-LINE MATERIAL UNDER DYNAMIC LOADING CONDITIONS

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SUMMARY

A series of tests has been conducted to investigate the elastic behavior of Viking-type suspension-line material under dynamic loading conditions. Results indicate that there is a decrease in both rupture-load capability and elongation at rupture as the test strain rate is increased. Preliminary examination of force-strain characteristics indicates that, on the average, the material exhibits some type of viscous effect which results in a greater force being produced, for a particular value of strain, under dynamic loading conditions than that produced under quasi-static loading conditions.

INTRODUCTION

Traditionally, analyses of parachute deployment and inflation dynamics have been conducted under the assumption of either a rigid or an undamped, linearly-elastic parachute suspension system. For some time, it has been known that the elastic behavior of typical dacron suspension-line materials under quasi-static (Instron) loading conditions is quite nonlinear. It has also been suspected that this elastic behavior might vary appreciably under dynamic loading conditions due to some type of viscous forces. The results presented in reference 1 show that suspension-line viscous damping can have a significant effect on the inflation dynamics of parachute systems such as the supersonic BLDT.

In light of the results presented in reference 1, a test program has been conducted to investigate the elastic characteristics of Viking-type suspension-line material under dynamic loading conditions. It is the purpose of this paper to present results obtained during the test program and to discuss conclusions that can be drawn from preliminary examination of the results.

TEST SYSTEM DESCRIPTION

The suspension-line material used in the tests was Type 52, 220 denier, 880-pound minimum tensile strength dacron cord which was procured from Goodyear Aerospace Corporation's supplier. It was specified that the material be identical to that supplied to GAC for the Viking parachute. Upon receipt at the Langley Research Center, the material was cut into sections of approximately 25 inches in length, and the sections were sterilized in accordance with instructions received from the Viking Project Office. The sections were then formed into test samples having Chinese-finger end loops and the dimensions shown in figure 1.

Quasi-static loading tests were performed on an Instron tensile-testing machine. Dynamic loading tests were performed by using a hydraulically-driven ram having a maximum-speed capability of about 39 in/sec. Samples were attached to pin-type fittings on the ram head and on a rigid base by using the Chinese-finger loops. Ram-head displacement was measured by using a cable-driven potentiometer, and force was measured by using a dynamically-calibrated resistance-type force gauge which was attached to the rigid base. In order to assure that data were properly recorded under the dynamic test conditions, a recording oscillograph was used for simultaneous recording of displacement and force readings. For both quasi-static and dynamic tests, specimens were strained to the point of rupture.

TEST RESULTS

Five loading tests were conducted using the Instron tensile-testing machine at a crosshead speed of 1 in/min. Assuming that the specimen gauge length is the distance between centers of the Chinese fingers, or 15 inches, this speed corresponds to a strain rate of 0.1 percent/sec. Force-strain curves for the five tests were essentially identical, and one such curve is shown in figure 2 as the representative quasi-static curve.

Figures 3 through 12 present force-strain curves for tests conducted using the hydraulic ram at strain rates varying from 4 percent/sec to 216 percent/sec. Fluctuation in calculated strain rates from test to test could be due to fluctuation in hydraulic flow rate or error in reading oscillograph charts. For all tests, sample rupture was seen to occur in the middle single-thickness region of the samples near the juncture of the end of the Chinese-finger loop.

By comparing figures 3 through 12 with the quasi-static curve in figure 2, several general observations can be noted:

1. The force-strain curves obtained under dynamic loading conditions on the average tend to lie above the quasi-static curve; i.e., for a particular value of strain, more force is produced under dynamic loading conditions than is produced under quasi-static conditions.
2. Material strain at time of rupture tends to decrease as strain rate is increased. For example, the average value of strain at rupture for the quasi-static tests is about 0.365; the average value for the tests near 210 percent/sec is about 0.29.
3. Rupture-load capability tends to decrease as strain rate is increased, as is summarized in figure 13 for the curves presented in figures 2 through 12 and for other tests for which force-strain curves are not

presented. The average rupture-load capability for the quasi-static tests is near 950 pounds; the average value decreases to about 810 pounds for tests near 200 percent/sec.

CONCLUSIONS

A great deal of uncertainty exists in defining a priori the tensile properties of viscoelastic materials, such as nylon or dacron, under dynamic loading conditions. Additional uncertainty enters the picture when woven configurations such as suspension-line material are considered. To eliminate these uncertainties, with respect to the Viking parachute configuration, a test program has been conducted to obtain data on the tensile properties of Viking-type suspension-line material over a wide range of strain rates. Based on preliminary examination of these data, the following conclusions can be drawn:

1. Material rupture-load capability decreases as strain-rate is increased. At strain rates above 75 percent/sec, no rupture loads were observed which would meet the minimum tensile strength specification of 880 pounds.
2. The material, on the average, exhibits some type of viscous effect which, for a particular value of strain, produces a greater load under dynamic loading conditions than that produced under quasi-static loading conditions.

REFERENCE

1. Poole, Lamont R.: Effects of Suspension-Line Damping on LADT #3 and Supersonic BLDT Parachute Inflation Dynamics. LWP-1050, May 1972.

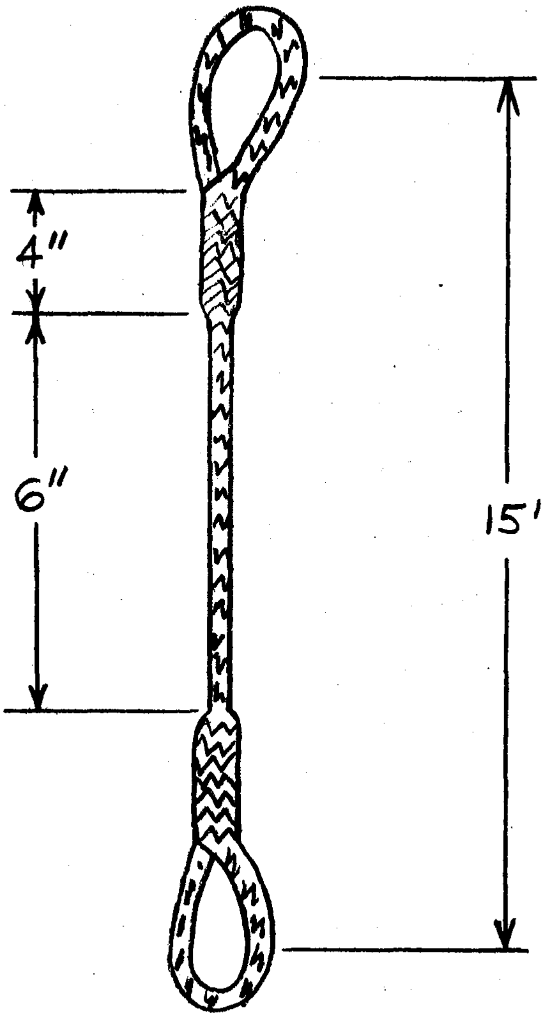

Figure 1.- Sketch of test sample configuration.

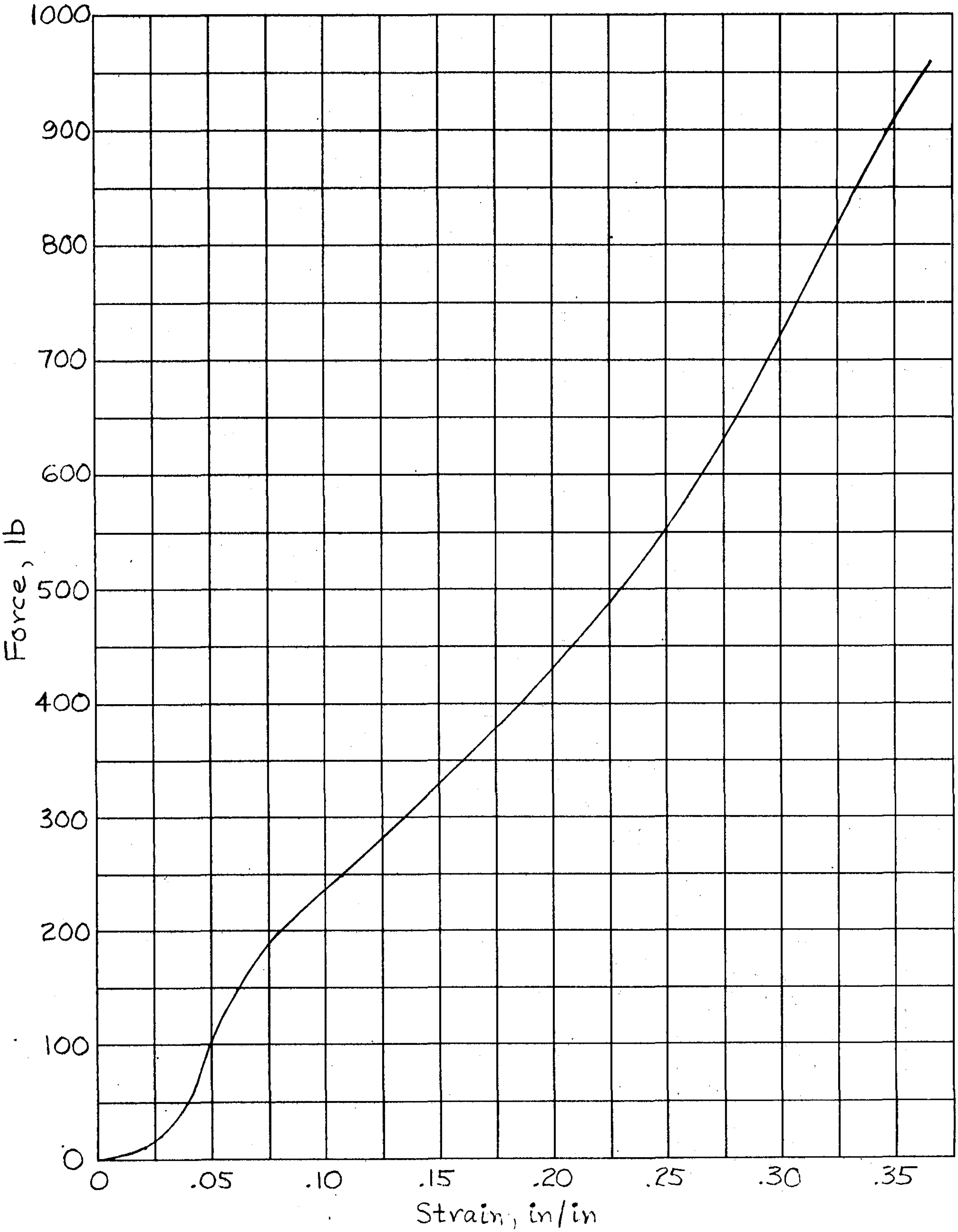

Figure 2.- Force-strain curve for samples tested in Instron at a strain rate of 0.1 %/sec.

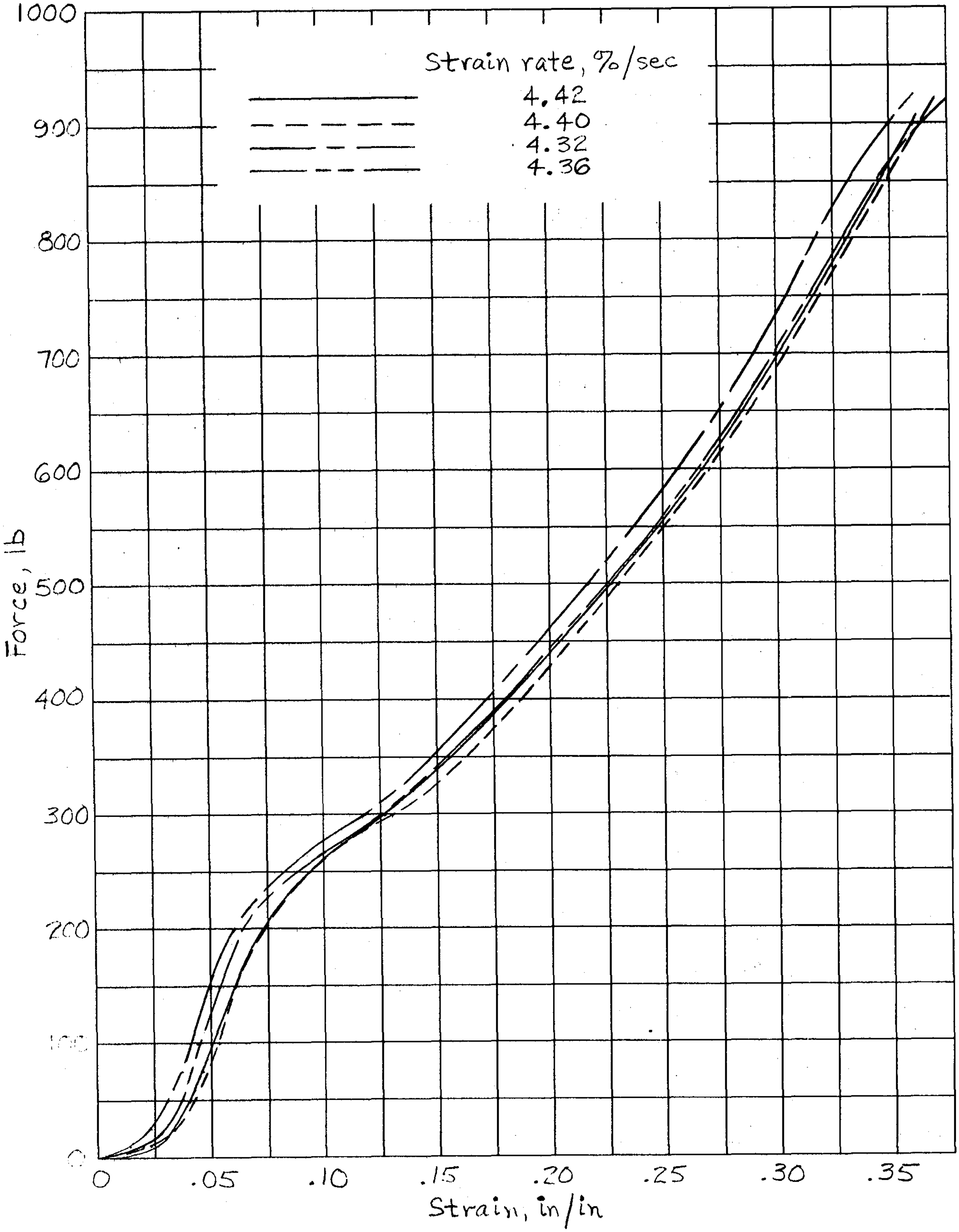

Figure 3.- Force-strain curves for samples tested at strain rates near 4 %/sec.

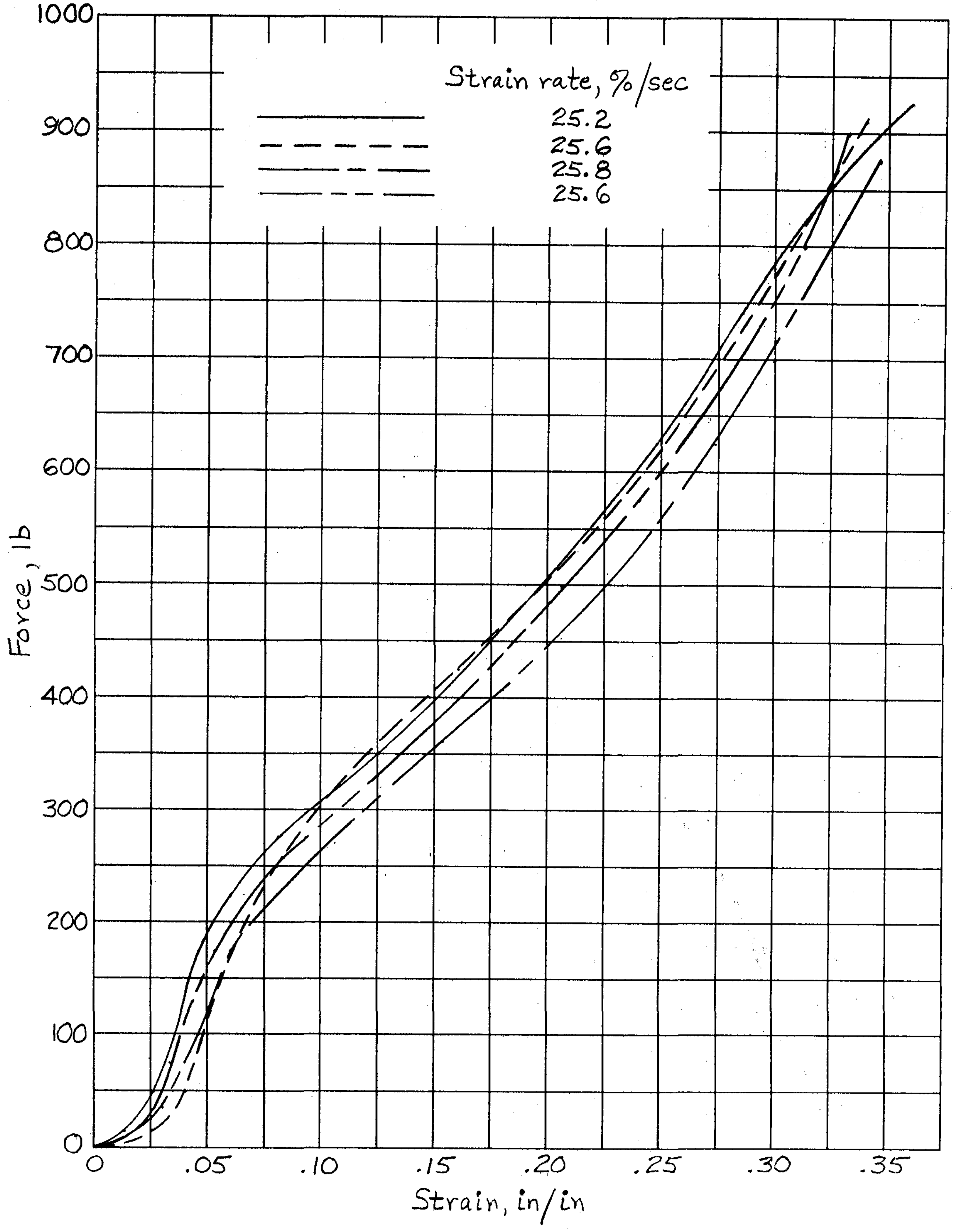

Figure 4.- Force-strain curves for samples tested at strain rates near 25 %/sec.

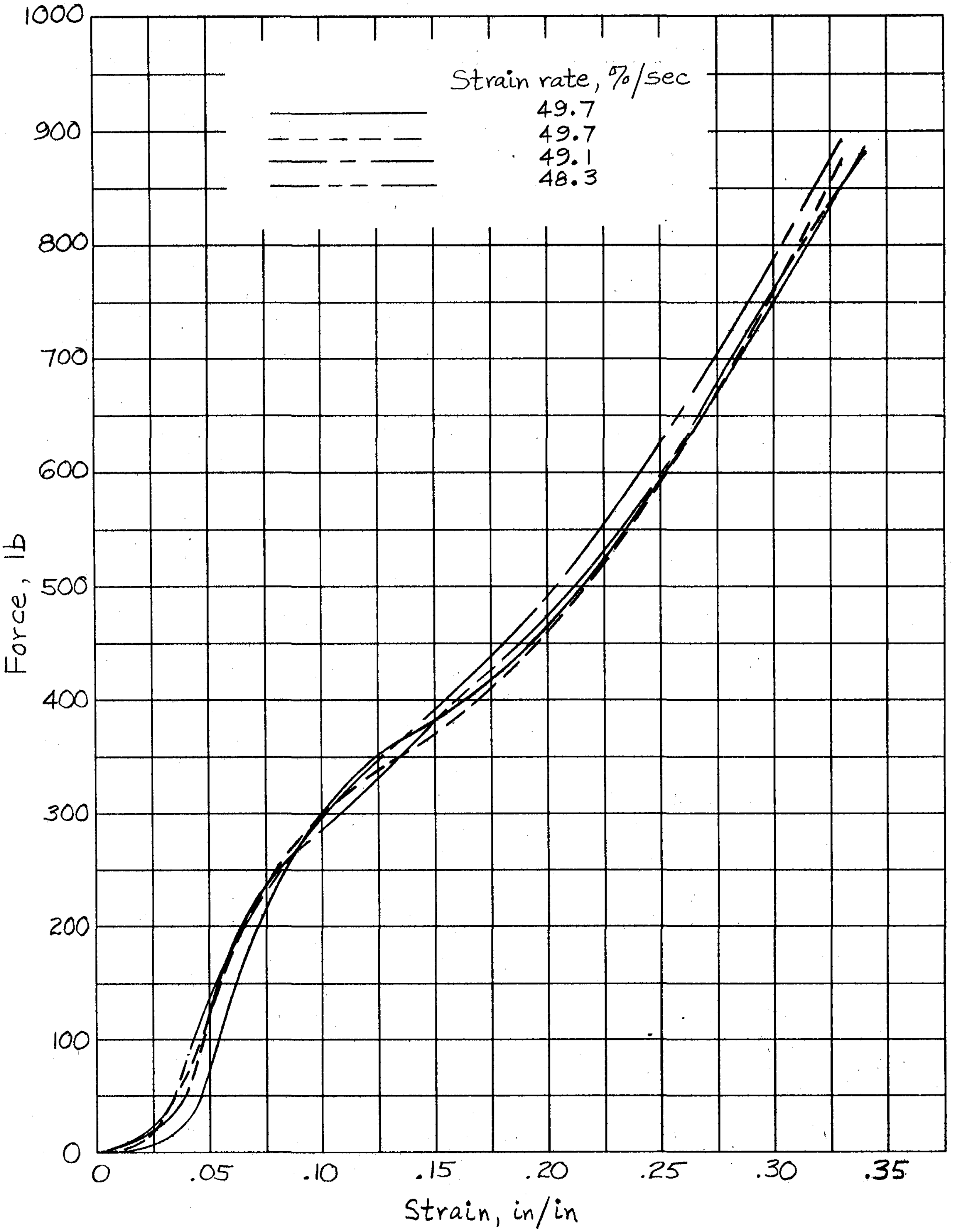

Figure 5.- Force-strain curves for samples tested at strain rates near 50 %/sec.

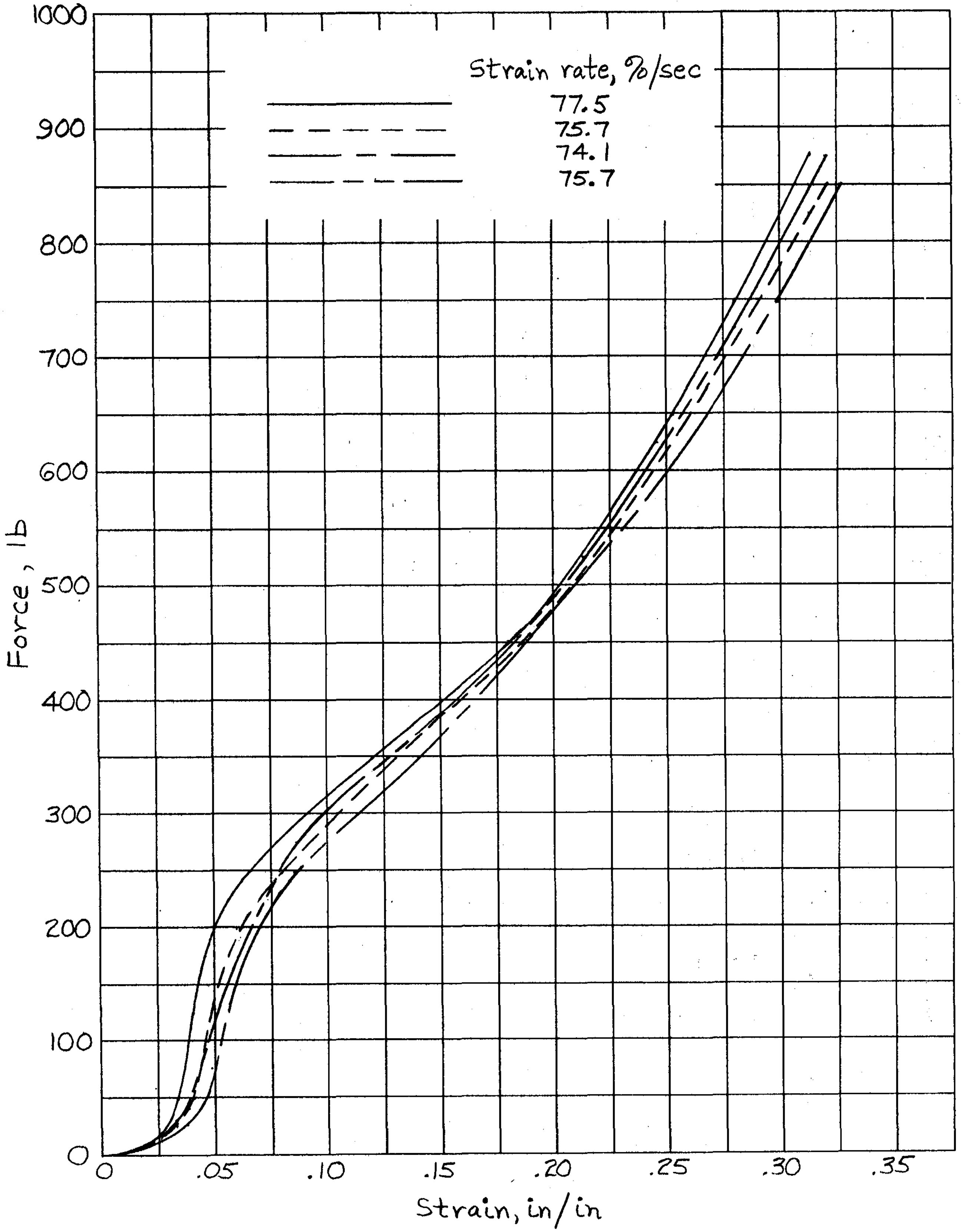

Figure 6.- Force-strain curves for samples tested at strain rates near 75 %/sec.

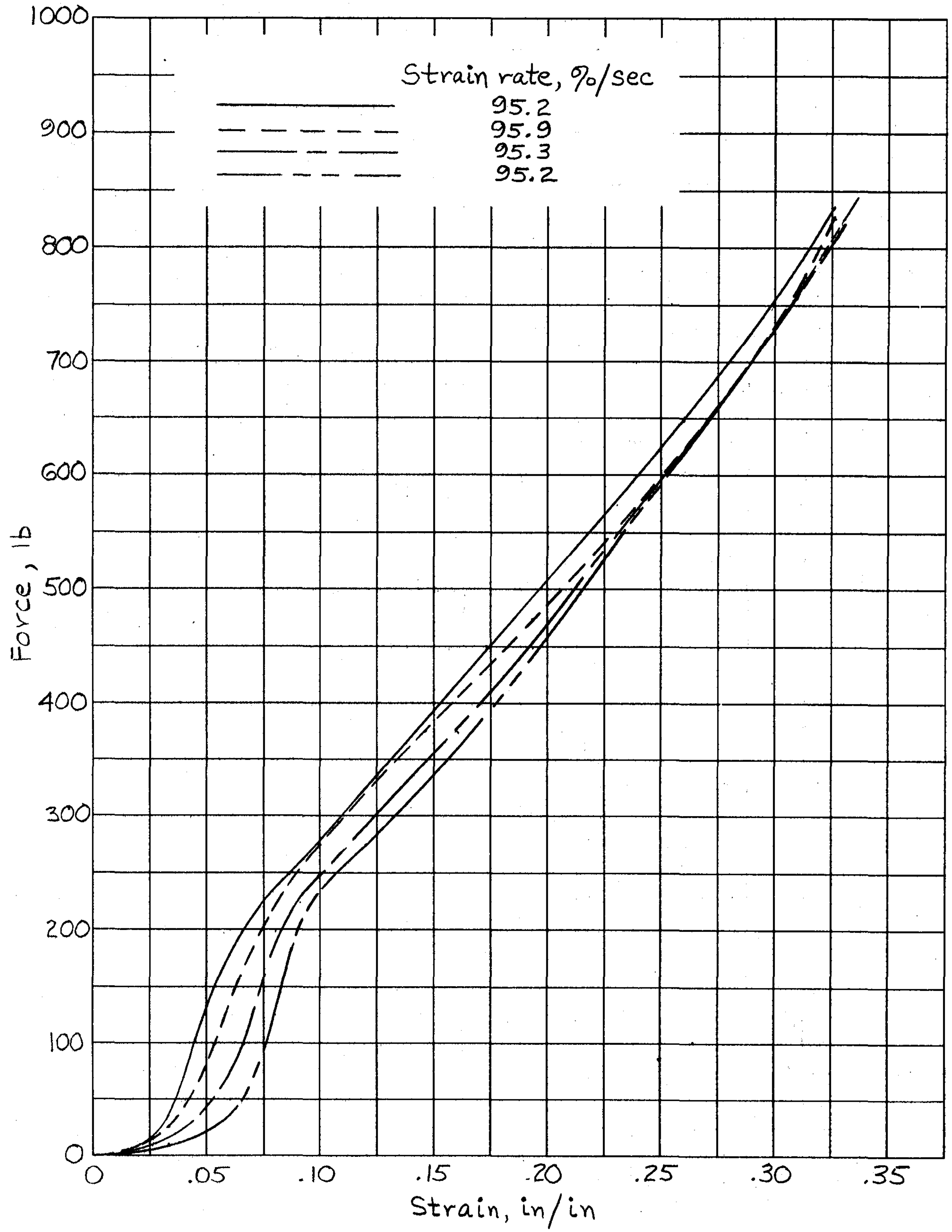

Figure 7.- Force-strain curves for samples tested at strain rates near 95 %/sec.

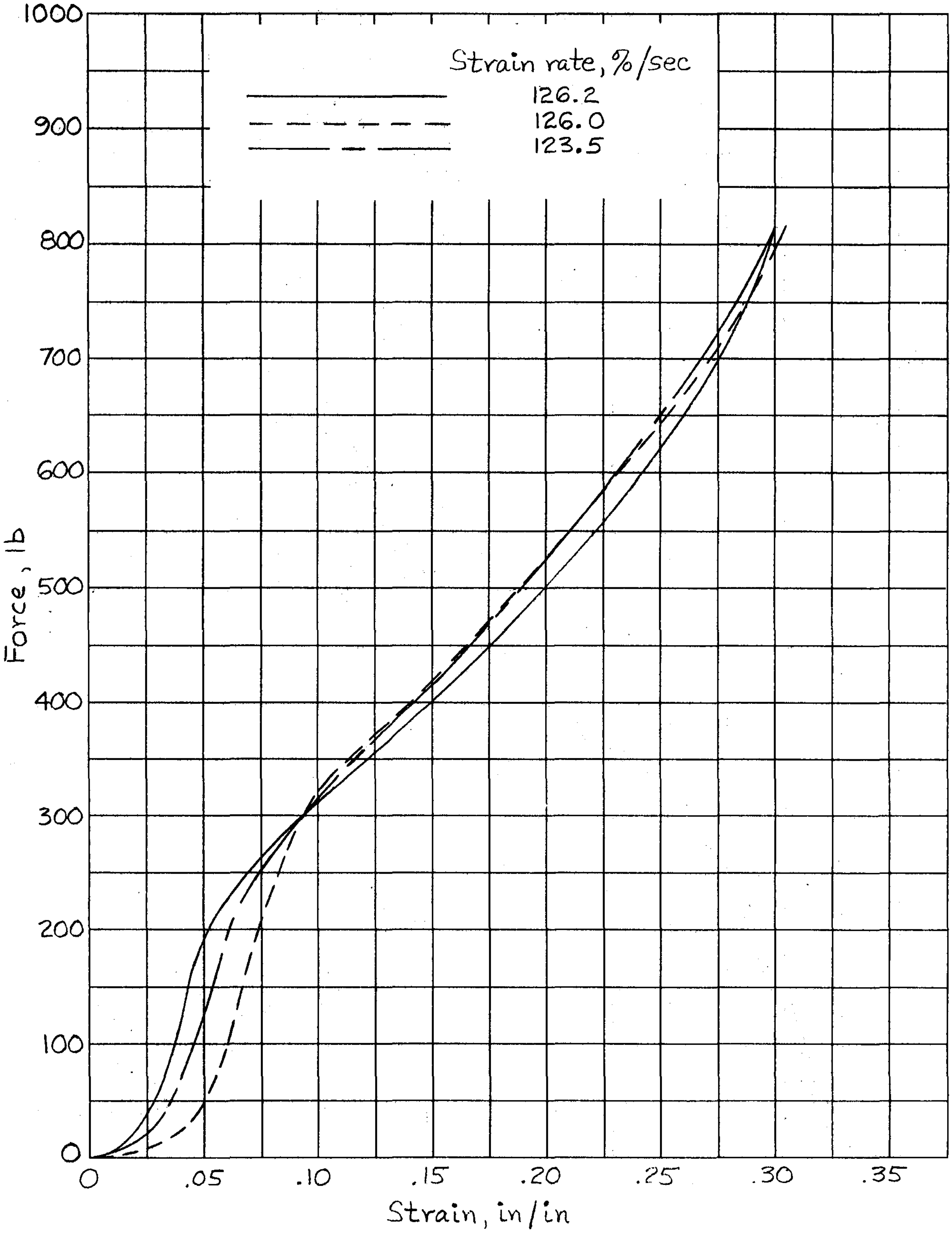

Figure 8.- Force-strain curves for samples tested at strain rates near 125 %/sec.

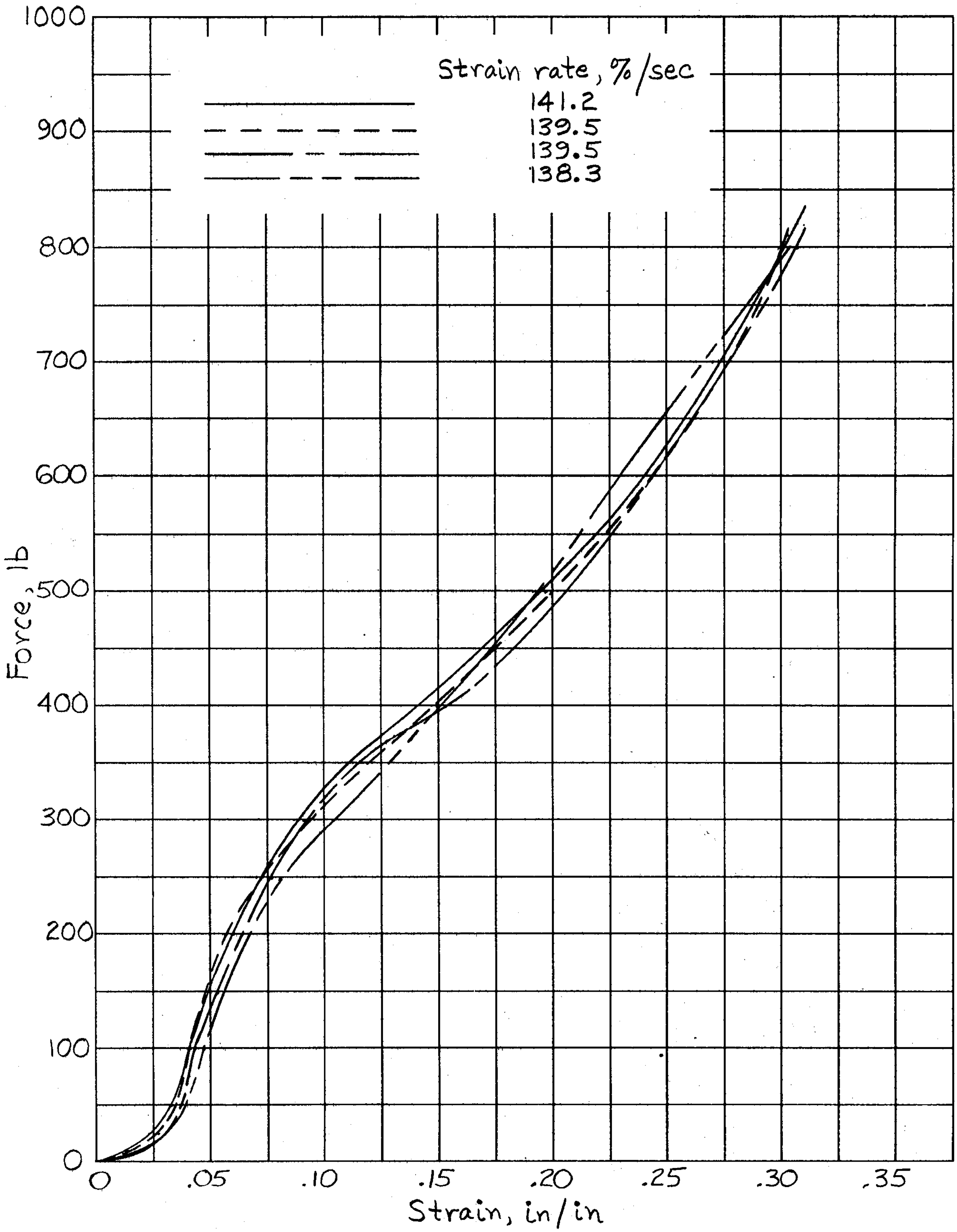

Figure 9.- Force-strain curves for samples tested at strain rates near 140 %/sec.

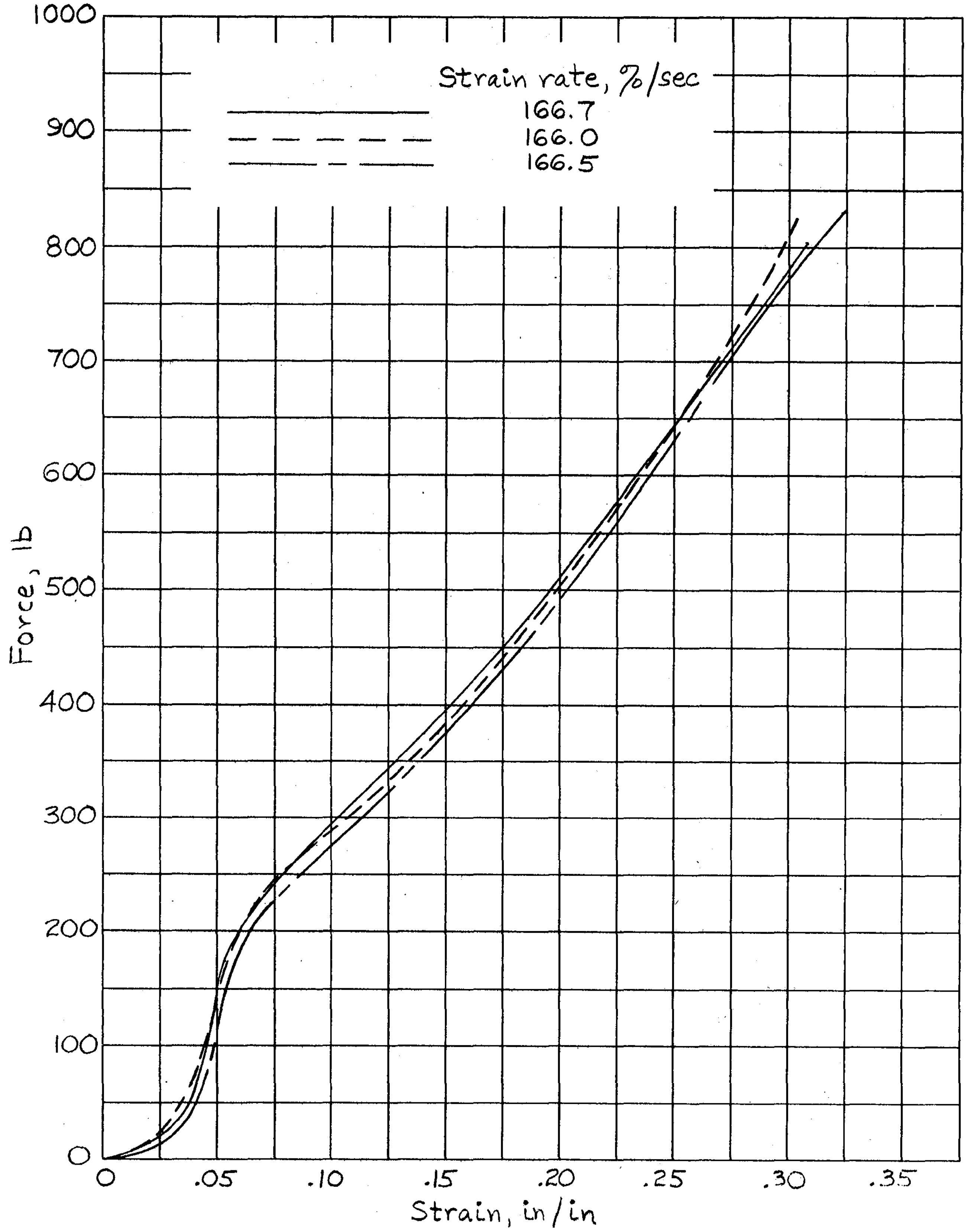

Figure 10.- Force-strain curves for samples tested at strain rates near 165 %/sec.

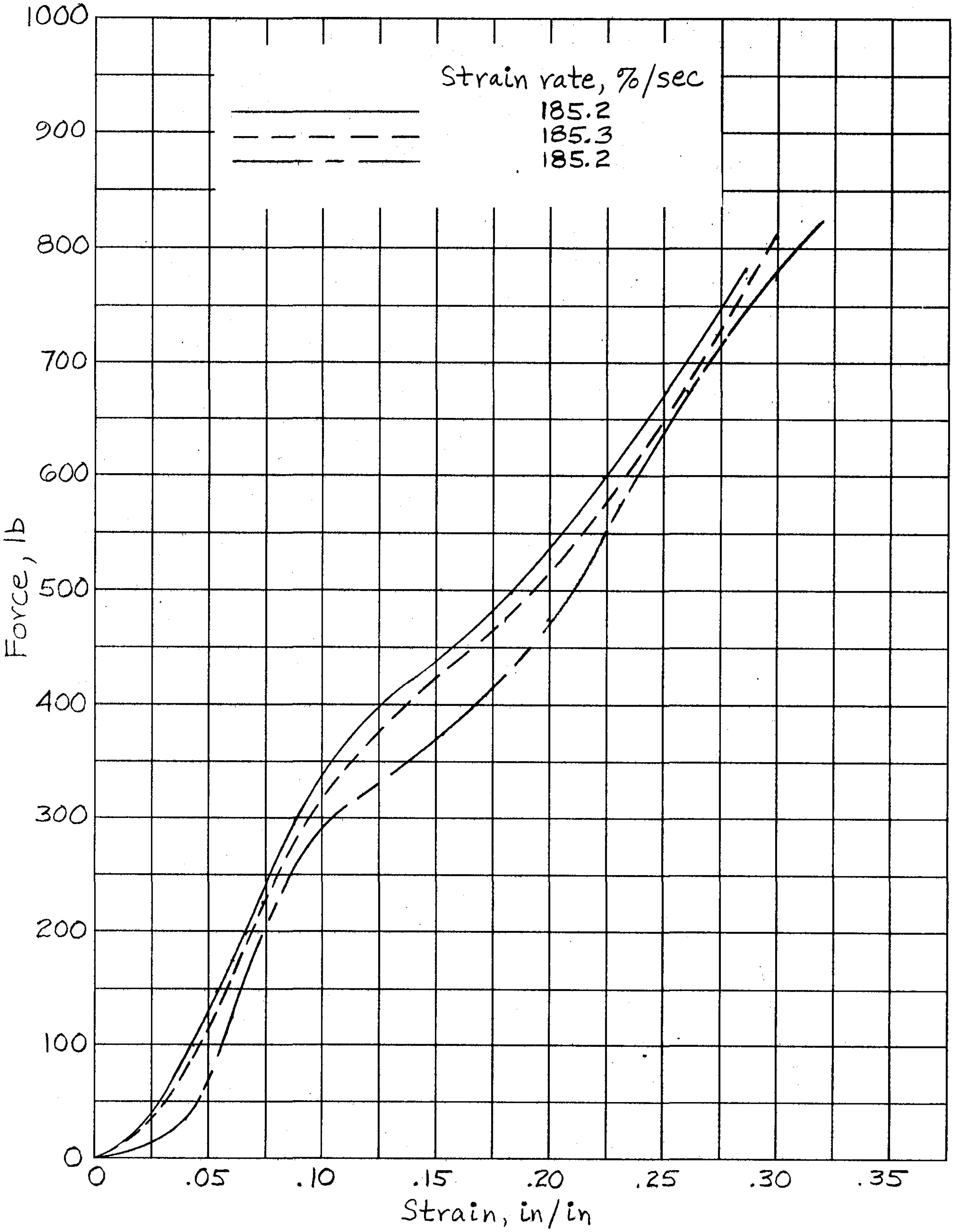

Figure 11. - Force-strain curves for samples tested at strain rates near 185 %/sec.

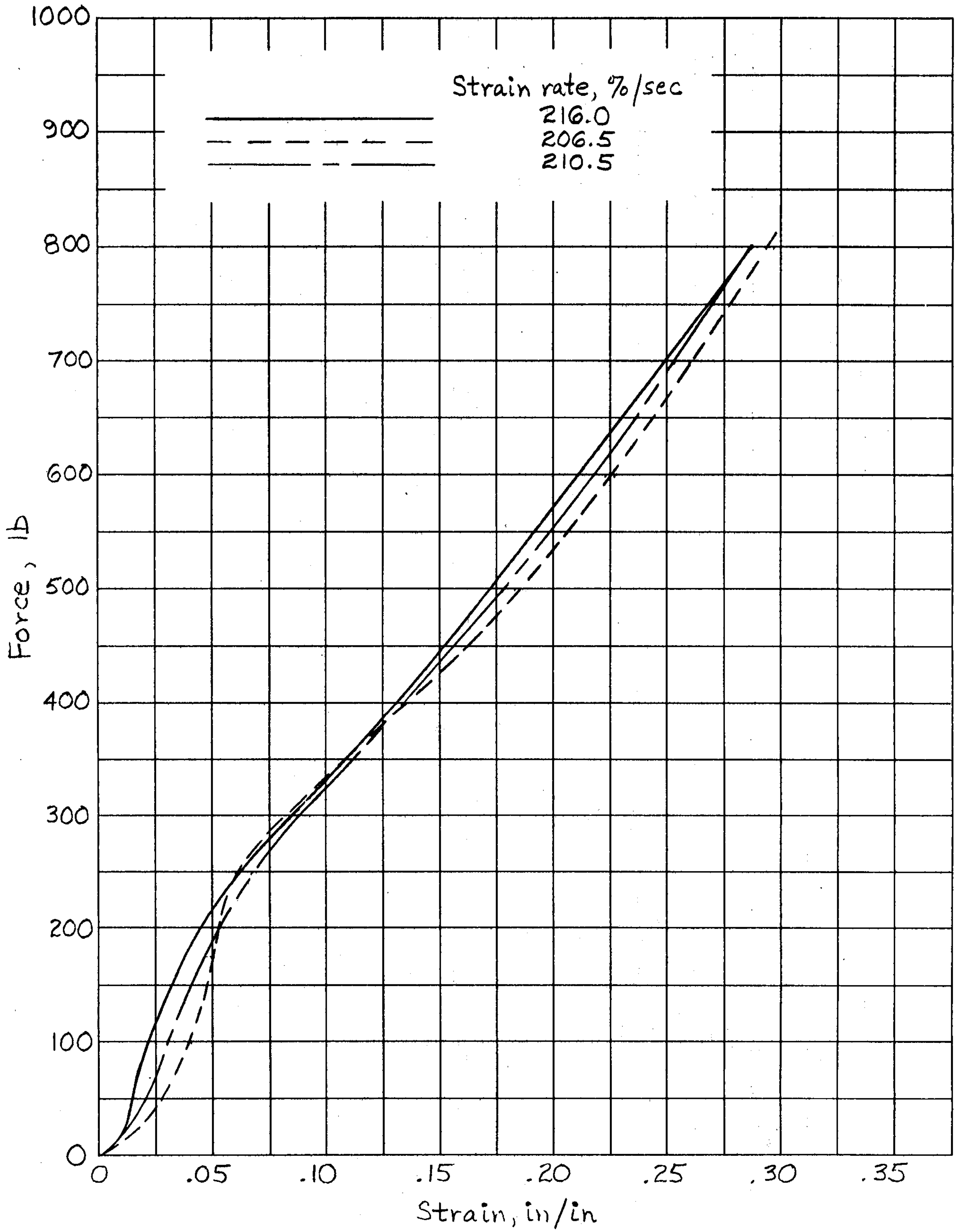

Figure 12.- Force-strain curves for samples tested at strain rates near 210 %/sec.

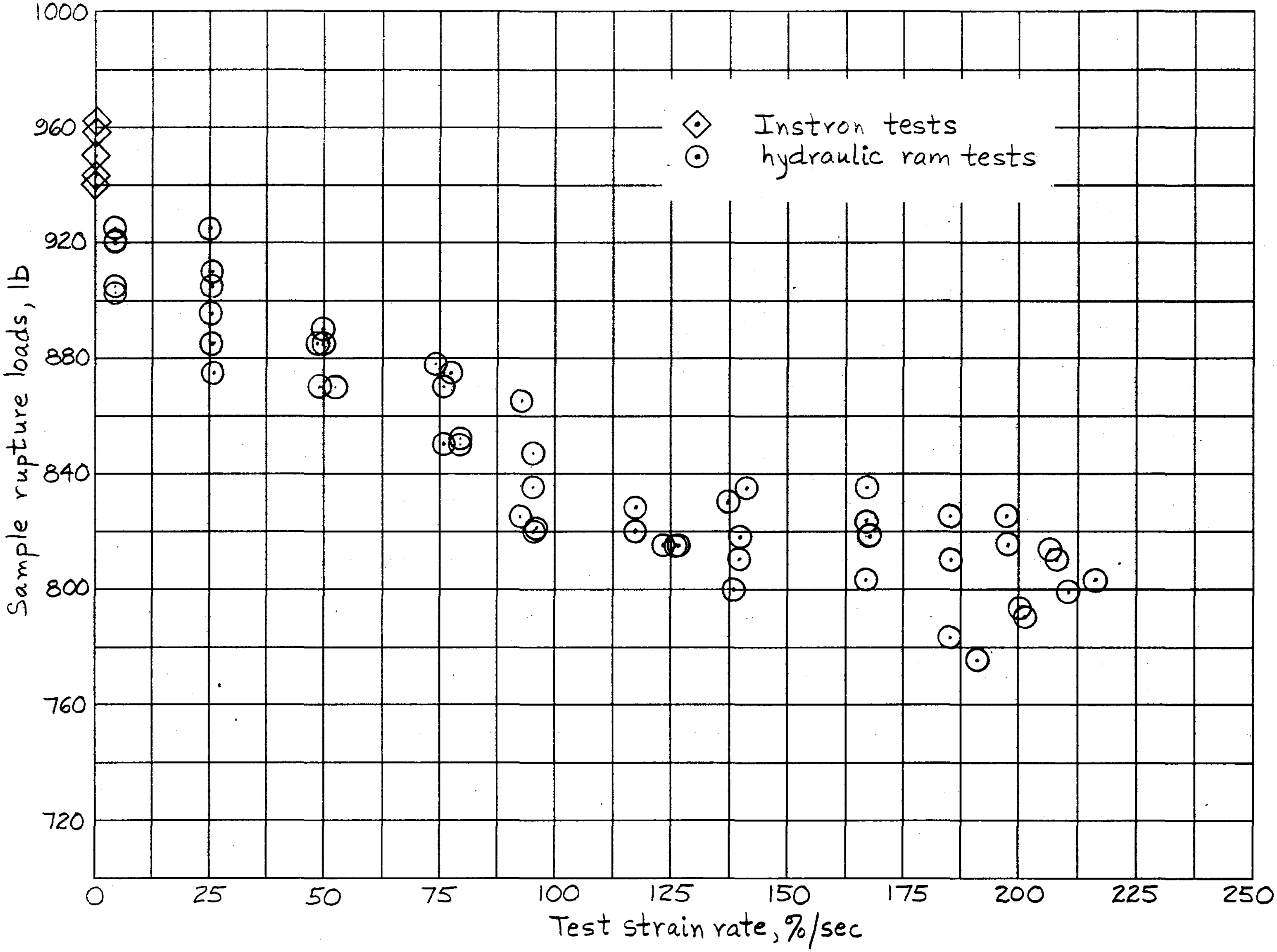

Figure 13.- Sample rupture loads as a function of strain rate at which samples were tested.