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Low Velocity Performance of an Impact-Deflection Anemometer

L. P. Purtell

National Bureau of Standards
Fluid Engineering Division
Washington, D.C. 20234

November 1978

Task Report

on
Contract No. H0166198
Evaluation of the Behavior of Mine Anemometers in the NBS Low Velocity Calibration Facility

Prepared for
United States Department of the Interior
Bureau of Mines

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and Process Technology
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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Performance of an impact-deflection anemometer is evaluated over the speed range of 42.3 to 709 feet per minute for five combinations of velocity probes and velocity ranges. The tests were performed in the NBS Low Velocity Airflow Facility which provides a uniform flow of low turbulence and utilizes a laser velocimeter as the velocity standard.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Airflow; anemometer; laser velocimeter; mine ventilation; low velocity; wind tunnel.

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- FOREWORD -

This report was prepared by the National Bureau of Standards, Fluid Engineering Division, Washington, D. C. 20234, under USBM Contract Number H0166198. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PM&SRC, with Dr. George H. Schnakenberg, Jr., acting as the Technical Project Officer. Mr. H. R. Eveland was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period December 1, 1977 to January 31, 1978. This report was submitted by the author November 1978.

LIST OF SYMBOLS

U	velocity measured by laser velocimeter
U_i	velocity indicated by anemometer under test
U_{if}	line segments fitted to U, U_i data
$\bar{U}$	group mean true velocity
$\bar{U}_i$	group mean indicated velocity
σ_i	standard deviation of U_i data from U_{if}
σ	standard deviation of U_i data expressed as true velocity
σ_c	σ adjusted for known variance in laser velocimeter measurements
R_i	resolution of the instrument
R	resolution expressed as true velocity

LOW VELOCITY PERFORMANCE OF AN IMPACT-DEFLECTION ANEMOMETER

L. P. Purtell

1. INTRODUCTION

The National Bureau of Standards in order to meet the need for a calibration capability with adequate accuracy at low air velocities, i.e., below 500 feet per minute (fpm) undertook the development of a low-velocity calibration facility for wind speed measuring instruments which would provide a capability down to 3 meters per minute (approximately 10 fpm) with an accuracy of plus or minus one percent. It was a natural consequence therefore that when said facility became operational to undertake an evaluation of the state-of-the-art and to provide the information needed as to the reliability and performance of instrumentation for such measurement. Accordingly, a number of prototypes of various types of instruments for low velocity air measurements are undergoing test at NBS, and this report is concerned specifically with the results of one such test.

2. THE INSTRUMENT

The anemometer tested for this report is a commercially available instrument (Alnor Instrument Company, Velometer, Series 6000-P)[1] used in the mining industry and elsewhere as a portable anemometer. It was supplied for test by the U. S. Mining Enforcement and Safety Administration at the request of the U. S. Bureau of Mines. The instrument (approximately 15 x 17 x 6 cm) contains an impact-deflection mechanism which deflects the needle indicator of a meter in response to the impact pressure from the airflow and consists of a main body meter with connections for one of several probes. The Pitot probe is composed of a cylinder 0.5 inches in diameter and 13 inches long which mounts in a range selector unit connected to the main body by hoses (Figure 1). The cylinder has ports to admit the airflow and must be properly oriented in the airstream to obtain a reading. The range selector may be set to one of two ranges, 100-1250 fpm (low range) and 100-2500 fpm (high range). Other range selectors are available, but were not tested herein.

The diffuser probe (Figure 2) is similar to the Pitot probe except that only impact pressure is utilized in the diffuser probe thus requiring a vent to be opened in the range selector for operation. It operates over the same ranges as the Pitot probe.

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[1] This particular instrument was selected as being representative of this type of anemometer and its selection does not represent an endorsement.

The low velocity probe (Figure 3.) attaches directly to the main body and operates like the Pitot probe except over a range of 30-300 fpm. Note that all the probes and the main body were mounted entirely within the wind tunnel since the flow is slightly below atmospheric pressure.

3. THE TEST

The NBS Low Velocity Airflow Facility [1] used to test this instrument generates a low velocity air stream having a low turbulence intensity (less than 0.05%) and a large region of uniform flow (at least 75 x 75 cm). A laser velocimeter is employed as a primary velocity standard. It is nonintrusive, has a linear response with velocity, and has good spatial resolution. Adequate sensitivity is obtained without the artificial seeding of scattering particles. Thus, the difficulties and inconvenience associated with seeding and the possible effect of such seeding on the performance of the device under test are avoided.

The anemometer was mounted on the centerline of the tunnel test section one meter downstream of the entrance to the test section in a manner to minimize the effect of the support on the air stream around the anemometer (Figures 1-3). Since the anemometer itself modifies the airflow in the tunnel, the velocity should be measured at a location in the flow which has the same velocity in the presence of the anemometer as it does in the absence of the anemometer. Since both the Pitot probe and the diffuser probe have small projected areas and are cylindrical, a distance of 30 cm upstream of the probes was chosen as the location for the laser velocimeter probe volume. Since 30 cm is approximately 24 diameters, disturbance to the flow should not be perceptible. This distance, 30 cm, has also been used for other tests (eg., [2]). The low velocity probe set-up, however, is quite large since the main body is attached directly to the probe. Thus measurements were made of the air velocity, U, at various distances upstream of the anemometer on the tunnel centerline at a freestream speed, U_∞, of 70 fpm. The ratio U/U_∞ is plotted in Figure 4 and shows that within the accuracy of the measurements (about 1%) the presence of the anemometer is not noticeable beyond about 25 cm. Thus, again 30 cm upstream of the anemometer was chosen as the location of the laser velocimeter probe volume. With no anemometer in the tunnel variation in velocity along the centerline is imperceptible over the distance traversed.

The air speed indicated by the anemometer was recorded during the time interval required for the measurement by the laser velocimeter. If fluctuations of the dial indicator were noticeable their magnitude was estimated and recorded. Five separate test runs were made for each speed range, and for each probe, a run consisting of eight different velocities for the Pitot and diffuser probes and seven for the low velocity probe. The lowest velocities were limited by instrument resolution and are 100 fpm for the low and high ranges and 40 fpm for the low velocity probe. The data are presented in chronological order in Tables 1A to 1E through 5A to 5E.

4. TEST RESULTS

Since a particular air speed in the wind tunnel cannot be exactly reset from run to run, scatter in the test data is distributed along a curve, thus prohibiting computing the standard deviation of the data from a simple average. Instead, deviations from a curve fit to the data were computed and the standard deviation approximated by the r.m.s. value of these deviations within a group. The groups are:

<u>Pitot probe, low range, fpm</u>

$U < 120$
$120 < U < 170$
$170 < U < 250$
$250 < U < 350$
$350 < U < 450$
$450 < U < 550$
$550 < U < 650$
$650 < U$

<u>Pitot probe, high range, fpm</u>

$U < 120$
$120 < U < 170$
$170 < U < 250$
$250 < U < 350$
$350 < U < 450$
$450 < U < 550$
$550 < U < 650$
$650 < U$

<u>Diffuser probe, low range, fpm</u>

$U < 120$
$120 < U < 170$
$170 < U < 250$
$250 < U < 350$
$350 < U < 450$
$450 < U < 550$
$550 < U < 650$
$650 < U$

<u>Diffuser probe, high range, fpm</u>

$U < 120$
$120 < U < 170$
$170 < U < 250$
$250 < U < 350$
$350 < U < 450$
$450 < U < 550$
$550 < U < 650$
$650 < U$

<u>Low velocity probe, fpm</u>

$U < 50$
$50 < U < 60$
$60 < U < 90$
$90 < U < 120$
$120 < U < 170$
$170 < U < 220$
$220 < U$

Since the groups of data are compact (small range of U within a group; see Figures 5 through 9, a straight line segment is used to approximate the curve within a group. The line segment passes through the point $(\bar{U},\bar{U}_i)$, the group mean true velocity and the group mean indicated velocity. The slope of the line segment is computed as the average of the slopes of two lines, both passing through $(\bar{U},\bar{U}_i)$ of the groups being considered, one line passing through the $(\bar{U},\bar{U}_i)$ of the adjacent group <u>higher</u> in velocity, and one line passing through $(\bar{U},\bar{U}_i)$ of the adjacent group <u>lower</u> in velocity. For the highest group of each test there is only one adjacent group, and thus the line segment for this highest group passes through $(\bar{U},\bar{U}_i)$ of that adjacent group. The line segments for the lowest groups are similarly formed.

Designating the above line segments as U_{if}, the standard deviation, σ_i of the indicated velocity, U_i, about the fitted segments is determined by squaring the differences between the U_i data and U_{if}, i.e., $[U_i(U) - U_{if}(U)]^2$. Since the data within the specified groups are reasonably compact, the mean of the squared differences within a group is taken as an estimate of the variance of U_i about U_{if} within that group and specified at that group's mean true velocity, $\bar{U}$. To convert this to a standard deviation in terms of <u>true</u> velocity, designated σ, each σ_i $(\bar{U})$ is divided by the slope (dU_{if}/dU) of the line segment associated with the σ_i $(\bar{U})$. Note that this σ does <u>not</u> include the "scatter" in the U measurements (due to the inability to exactly reset the wind tunnel to a specified speed), but <u>does</u> include the uncertainty in a particular laser velocimeter measurement. This uncertainty may be estimated from repeated measurements of velocity at a particular fan setting, thus also including any unsteadiness in the velocity, and is estimated as 0.001U for this report. A standard deviation, σ_c, corrected for the laser velocimeter uncertainty may thus be computed from

$$\sigma_c^2 = \sigma^2 - (0.001U)^2$$

for any given U. σ and σ_c are presented in Figures 10 through 14 as velocity and in Figures 15 through 19 as percentage of $\bar{U}$. Since $\pm 2\sigma_c$ is extremely close to the 95 percent confidence interval for one measurement, curves of $\pm 2\sigma_c$ are also included in Figures 5 through 9 as dashed lines.

The actual differences between the true and indicated velocities, $U - U_i$, are presented in Figures 20 through 24 and as a percentage of U in Figures 25 through 29. The curves shown in each figure have been drawn for reference only.

5. DISCUSSION OF RESULTS

Computing σ from measurements by an instrument having a scale with a resolution, R_i, much smaller than σ_i is a good procedure for determining repeatability of the instrument. If the resolution is <u>large</u> (poor) compared to σ_i (where σ_i is presumed known by some means independent of the scale being considered, say by a second scale with better resolution), the indicated σ may be much smaller than it should be. For a Gaussian distribution of errors it is assumed that σ_i may be adequately computed if the resolution is at most approximately twice σ_i. The following values of resolution were judged to be the best that can be read on the anemometer tested:

<u>Low Range</u>

$100 < U_i < 200$ fpm, R_i = 1 division or 20 fpm

$200 < U_i < 600$ fpm, R_i = 1/2 division or 10 fpm

$600 < U_i < 1250$ fpm, R_i = 1/4 division or 5 fpm

<u>High Range</u>

$100 < U_i < 500$ fpm, R_i = 1/2 division or 25 fpm

$500 < U_i < 2500$ fpm, R_i = 1/5 division or 10 fpm

<u>Low Velocity Probe</u>

$20 < U_i < 200$ fpm, R_i = 1/2 division or 2.5 fpm

$200 < U_i < 300$ fpm, R_i = 1/5 division or 1 fpm

As with the computed values of σ_i, these values of resolution, R_i were converted to equivalent values, R, in terms of true velocity by dividing by the slope (dU_{if}/dU). These latter values, divided by two, were then included in Figures 10 through 14 in units of velocity and in Figures 15 through 19 as percentage of $\bar{U}$. As may be seen in Figures 10 through 14, R/2 does indeed exceed σ for most of the measurements. Thus these values of σ should be taken with reservation and perhaps replaced by the values R/2. The performance of the instrument in these instances in terms of repeatability may exceed the quality of its resolution. The instrument in general performed with no erratic behavior. Some general comments concerning application of the instrument follow. With any measurement problems the instrument's capabilities should be matched to the required measurement.

This anemometer is intrusive, i.e., it must be placed in the flow.

This anemometer is entirely mechanical and does not require an outside source of power.

Many factors that can affect the suitability of an instrument for a particular application, such as turbulence or unsteadiness of the air stream, rough handling (shock and vibration), dirt and other environmental factors, time, orientation to the velocity and gravity vectors, etc., have not been tested herein but should be considered.

6. SUMMARY

The performance of an impact-deflection anemometer has been evaluated at air speeds up to 709 fpm. Evaluation of the repeatability was found to involve considering the resolution of the instrument. Figures are presented showing the deviation of indicated velocity from true velocity and the standard deviation of repeated runs about the mean curves. The lowest velocities measurable were limited by resolution of the instrument and were 100 fpm for the low and high ranges and 40 fpm for the low velocity probe.

7. REFERENCES

1. L. P. Purtell and P. S. Klebanoff, The NBS Low Velocity Airflow Facility, in preparation.

2. L. P. Purtell, Low Velocity Performance of a Bronze Bearing Vane Vane Anemometer, NBSIR 781433.

Table 1A
Alnor Velometer
Series 6000-P
Pitot probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
100	102
140	153
190	198
285	297
380	400
468	498
560	603
645	705

T = 21.1 °C
B = 739.5 mm Hg

Table 1B
Alnor Velometer
Series 6000-P
Pitot probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
100	102
140	154
190	199
280	297
378	400
468	499
558	604
645	705

T = 21.1 °C
B = 739.5 mm Hg

Table 1C
Alnor Velometer
Series 6000-P
Pitot probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
100	102
140	153
190	198
280	297
380	401
470	498
560	605
645	706

T = 21.8 °C
B = 740.1 mm Hg

Table 1D
Alnor Velometer
Series 6000-P
Pitot probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
100	102
140	153
188	198
285	297
378	401
468	498
560	603
645	704

T = 21.8 °C
B = 740.1 mm Hg

Table 1E
Alnor Velometer
Series 6000-P
Pitot probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
100	102
140	153
192	198
285	297
378	402
470	497
560	602
648	709

T = 21.8 °C
B = 741.0 mm Hg

Table 2A
Alnor Velometer
Series 6000-P
Pitot probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
75	103
125	149
190	201
300	300
410	399
540	502
645	604
760	705

T = 21.1 °C
B = 749.2 mm Hg

Table 2B
Alnor Velometer
Series 6000-P
Pitot probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
75	103
130	149
190	200
295	299
420	399
540	503
655	604
755	707

T = 21.1 °C
B = 749.2 mm Hg

Table 2C
Alnor Velometer
Series 6000-P
Pitot probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
80	103
130	149
195	200
300	300
435	399
540	503
650	606
755	706

T = 21.1 °C
B = 749.3 mm Hg

Table 2D
Alnor Velometer
Series 6000-P
Pitot probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
80	103
135	149
185	200
305	300
425	399
540	503
645	605
750	704

T = 21.1 °C
B = 749.3 mm Hg

Table 2E
Alnor Velometer
Series 6000-P
Pitot probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
75	103
125	149
190	200
300	300
420	398
540	503
650	605
755	705

T = 21.1 °C
B = 749.3 mm Hg

Table 3A
Alnor Velometer
Series 6000-P
Diffuser probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
75	101
145	148
230	201
395	301
540	401
675	501
820	602
940	701

T = 21.1 °C
B = 747.8 mm Hg

Table 3B
Alnor Velometer
Series 6000-P
Diffuser probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
75	101
145	149
240	200
395	301
545	401
680	503
815	602
940	698

T = 21.1 °C
B = 747.8 mm Hg

Table 3C
Alnor Velometer
Series 6000-P
Diffuser probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
80	101
145	149
245	200
400	301
540	401
680	499
820	601
940	699

T = 21.1 °C
B = 747.5 mm Hg

Table 3D
Alnor Velometer
Series 6000-P
Diffuser probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
90	101
150	147
240	201
395	301
545	400
675	501
825	600
945	698

T = 21.1 °C
B = 747.5 mm Hg

Table 3E
Alnor Velometer
Series 6000-P
Diffuser probe-2500 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
90	101
150	148
245	200
395	301
540	400
680	500
815	599
940	698

T = 21.1 °C
B = 747.3 mm Hg

Table 4A
Alnor Velometer
Series 6000-P
Diffuser probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
135	101
195	149
280	199
395	300
510	401
620	498
735	601
840	698

T = 21.1 °C
B = 746.0 mm Hg

Table 4B
Alnor Velometer
Series 6000-P
Diffuser probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
130	101
200	148
278	198
398	299
515	399
620	498
738	599
840	699

T = 21.1 °C
B = 746.0 mm Hg

Table 4C
Alnor Velometer
Series 6000-P
Diffuser probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
130	102
200	149
278	199
400	300
515	401
620	500
740	602
840	697

T = 21.1 °C
B = 745.4 mm Hg

Table 4D
Alnor Velometer
Series 6000-P
Diffuser probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
135	101
200	149
278	200
398	301
515	402
618	501
738	601
843	701

T = 21.1 °C
B = 745.4 mm Hg

Table 4E
Alnor Velometer
Series 6000-P
Diffuser probe-1250 Scale

Indicated Air Speed, fpm	True Air Speed, fpm
138	101
200	148
275	199
395	301
518	401
620	499
738	603
840	696

T = 20.6 °C
B = 744.3 mm Hg

Table 5A
Alnor Velometer
Series 6000-P
Low Velocity probe

Indicated Air Speed, fpm	True Air Speed, fpm
33	43.0
47	56.5
68	77.6
93	102
145	150
207	199
297	271

T = 20.6 °C
B = 742.5 mm Hg

Table 5B
Alnor Velometer
Series 6000-P
Low Velocity probe

Indicated Air Speed, fpm	True Air Speed, fpm
33	42.9
45	56.5
66	77.4
94	101
145	150
207	199
296	272

T = 20.6 °C
B = 742.5 mm Hg

Table 5C
Alnor Velometer
Series 6000-P
Low Velocity probe

Indicated Air Speed, fpm	True Air Speed, fpm
32	42.6
46	56.1
67	77.6
92	101
146	149
207	199
295	270

T = 20.0 °C
B = 742.0 mm Hg

Table 5D
Alnor Velometer
Series 6000-P
Low Velocity probe

Indicated Air Speed, fpm	True Air Speed, fpm
34	42.9
45	55.8
68	77.3
93	101
144	149
208	198
295	271

T = 20.0 °C
B = 742.0 mm Hg

Table 5E
Alnor Velometer
Series 6000-P
Low Velocity probe

Indicated Air Speed, fpm	True Air Speed, fpm
33	42.3
48	56.9
68	77.6
94	102
144	149
207	199
296	272

T = 20.0 °C
B = 740.3 mm Hg

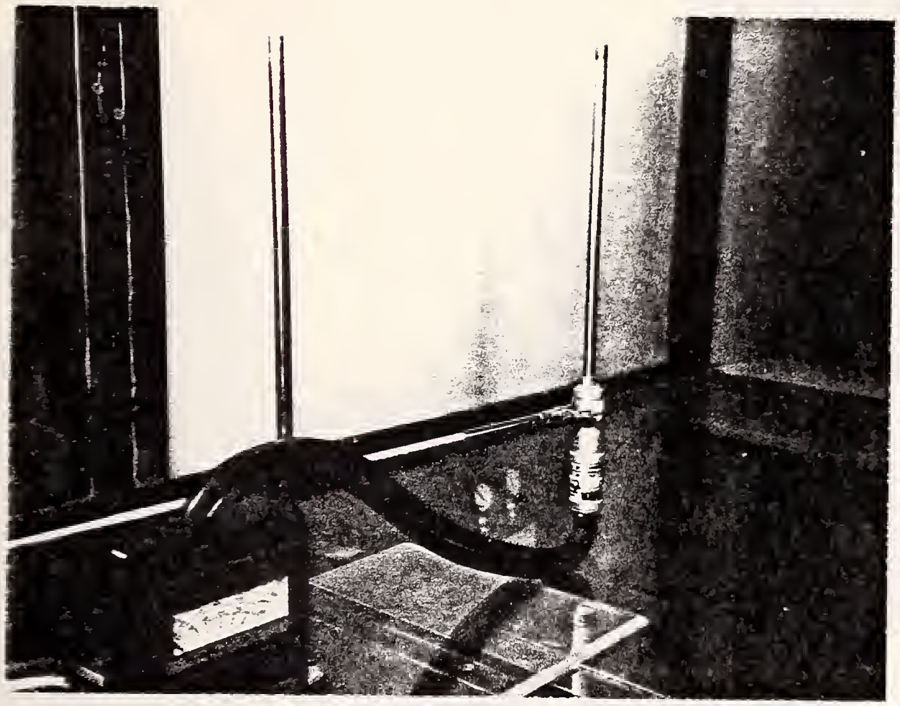


FIGURE 1. THE ANEMOMETER WITH PITOT PROBE MOUNTED IN TUNNEL SHOWING METHOD OF SUPPORT.

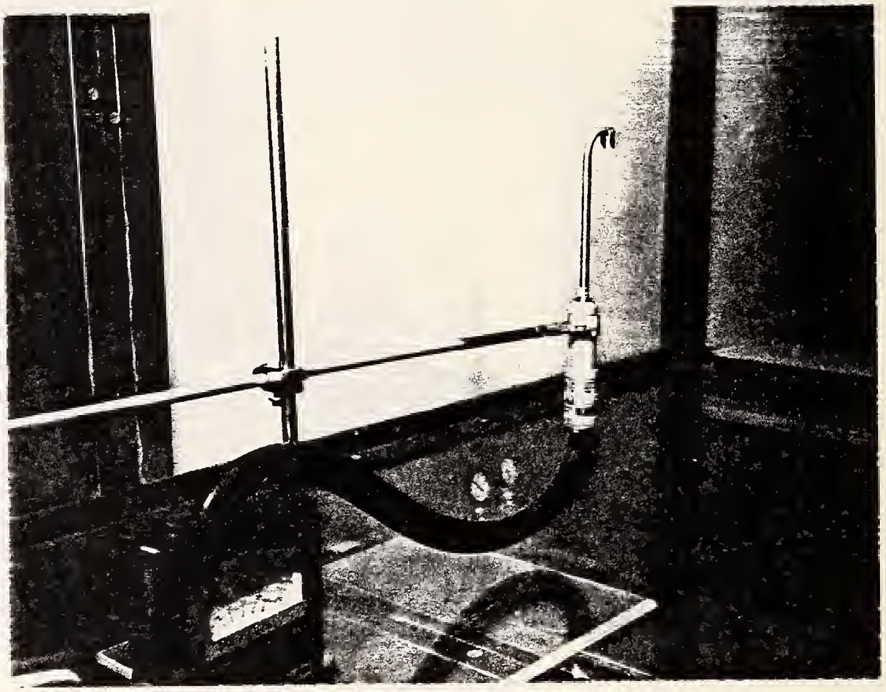


FIGURE 2. THE ANEMOMETER WITH DIFFUSER PROBE MOUNTED IN TUNNEL SHOWING METHOD OF SUPPORT.

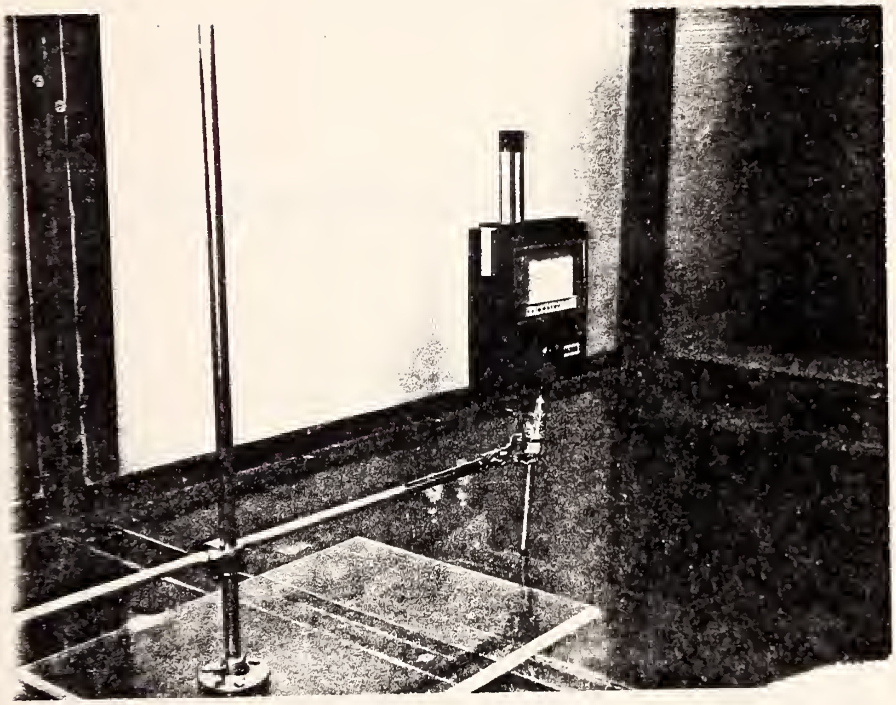
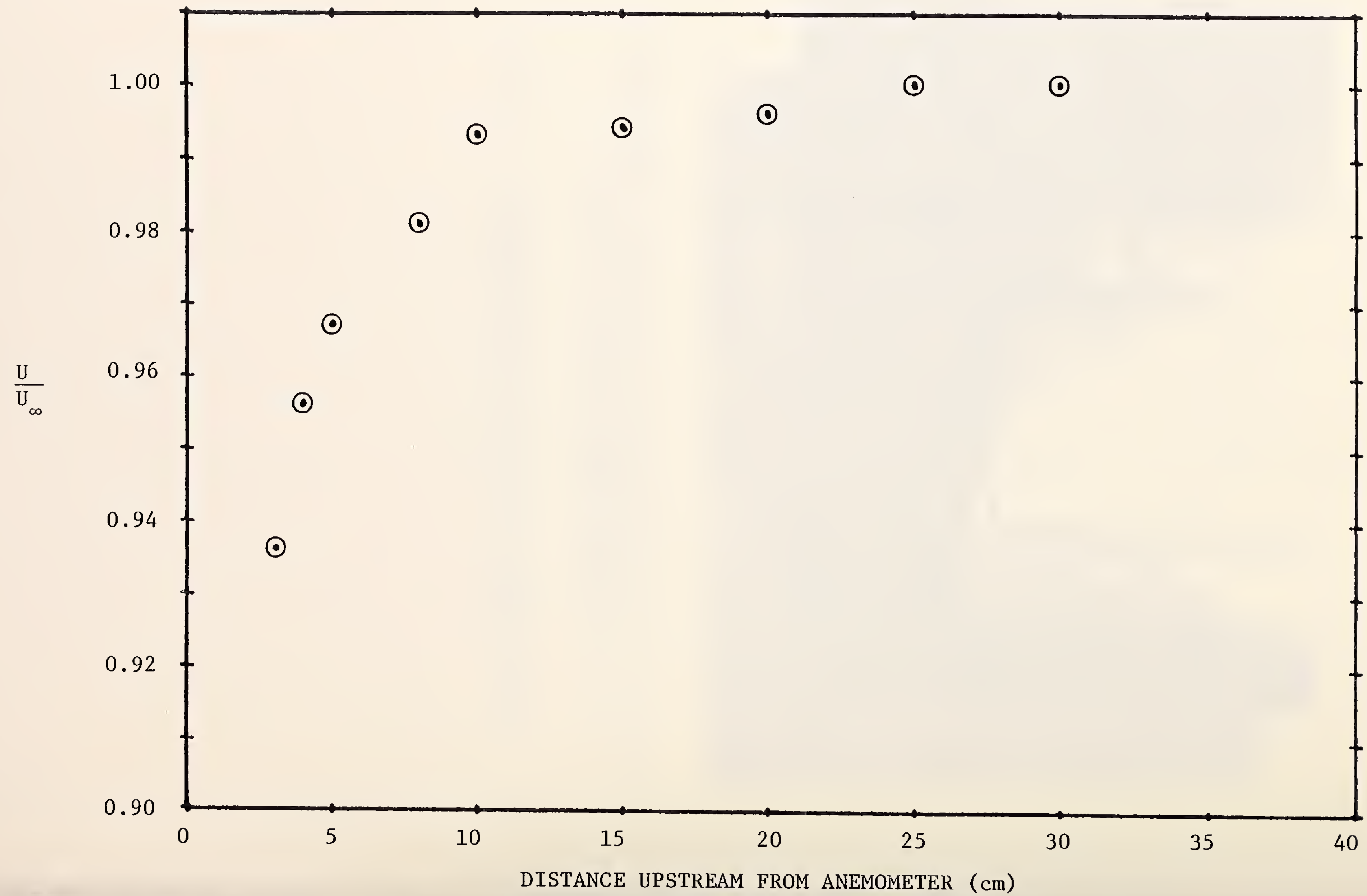


FIGURE 3. THE ANEMOMETER WITH LOW-VELOCITY PROBE MOUNTED IN TUNNEL SHOWING METHOD OF SUPPORT.



$\frac{U}{U_\infty}$
1.00
0.98
0.96
0.94
0.92
0.90
0
5
10
15
20
25
30
35
40
DISTANCE UPSTREAM FROM ANEMOMETER (cm)

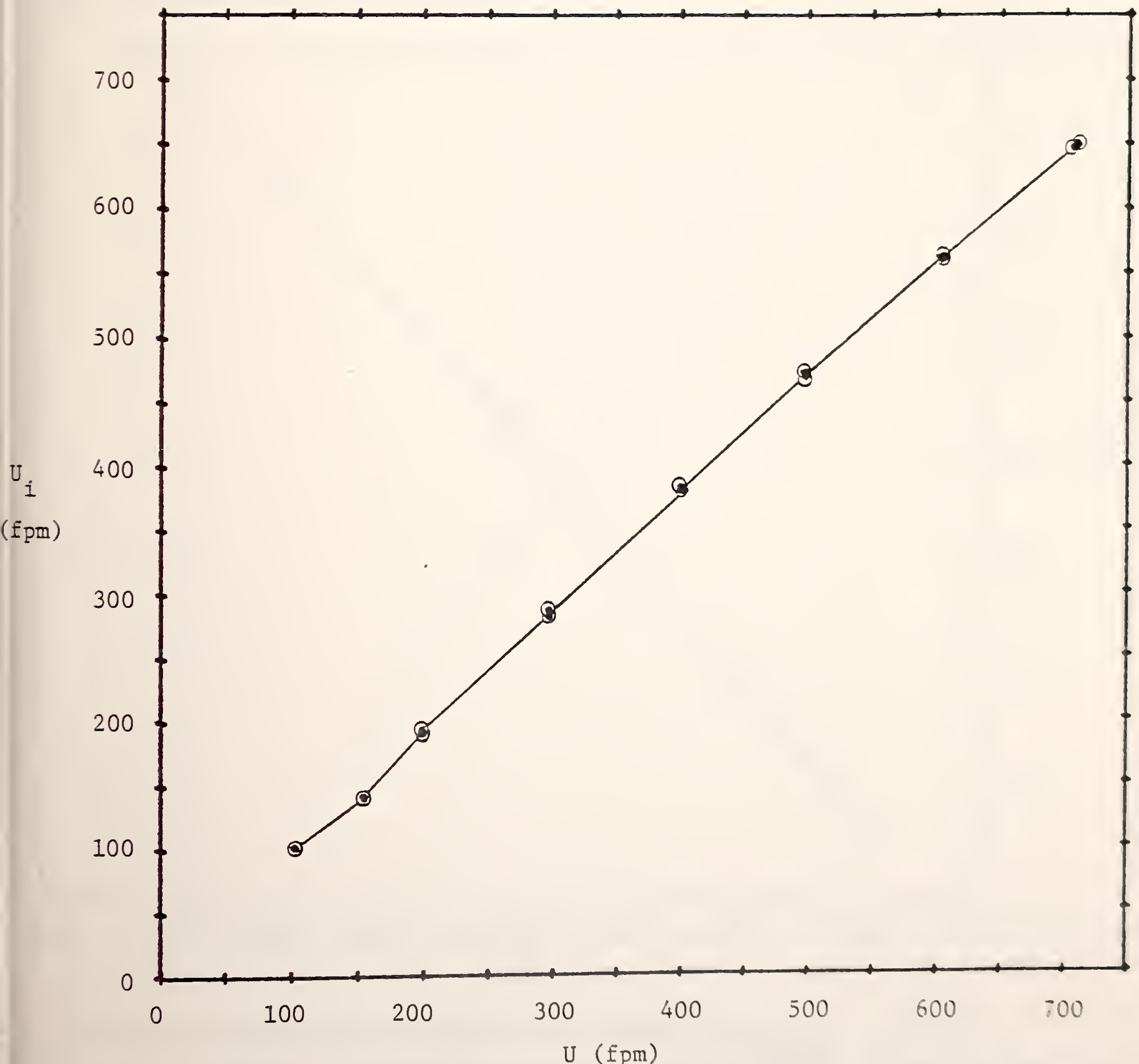


FIGURE 5. INDICATED VERSUS TRUE VELOCITY FOR PITOT PROBE, LOW RANGE.

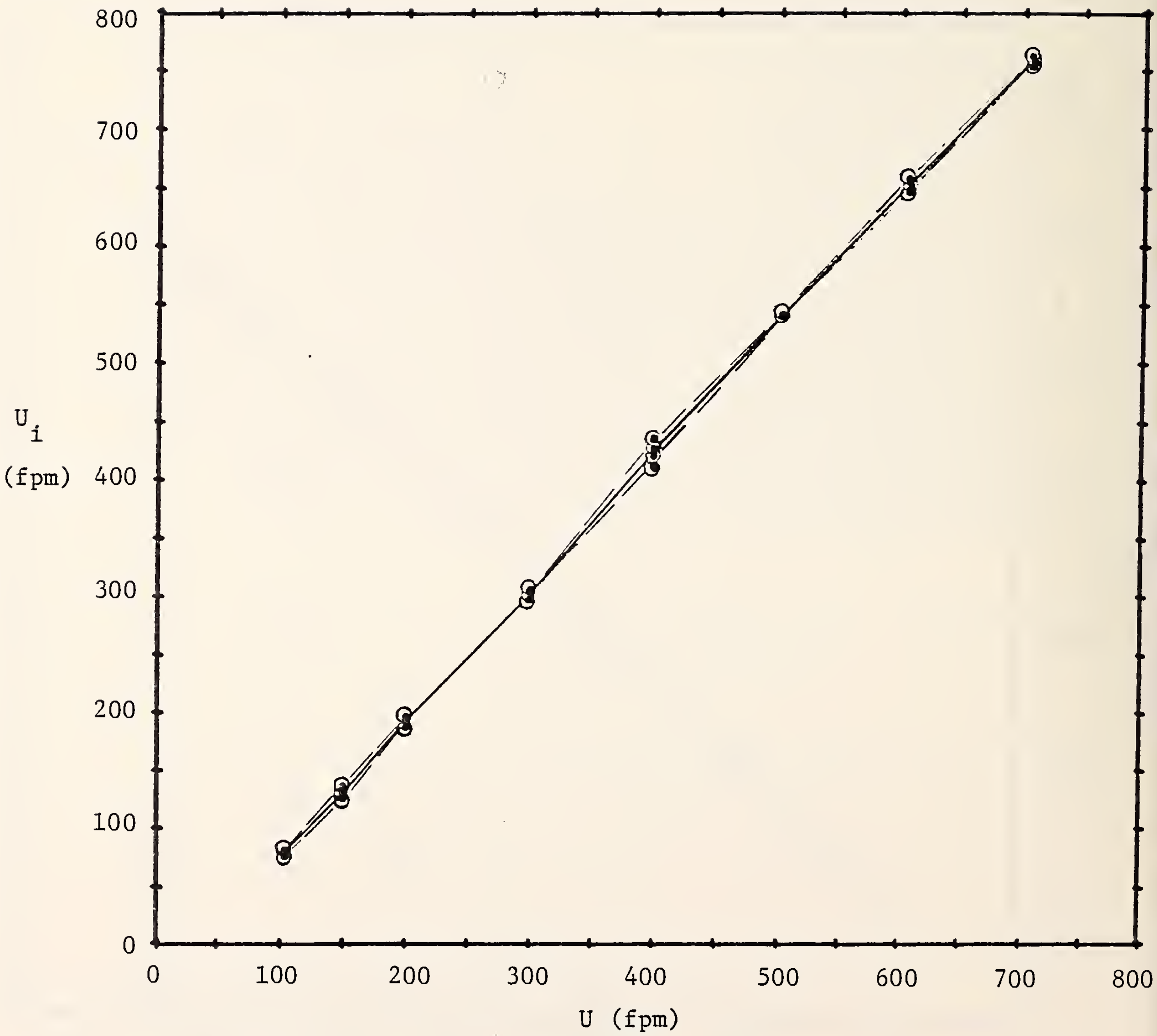


FIGURE 6. INDICATED VERSUS TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE.

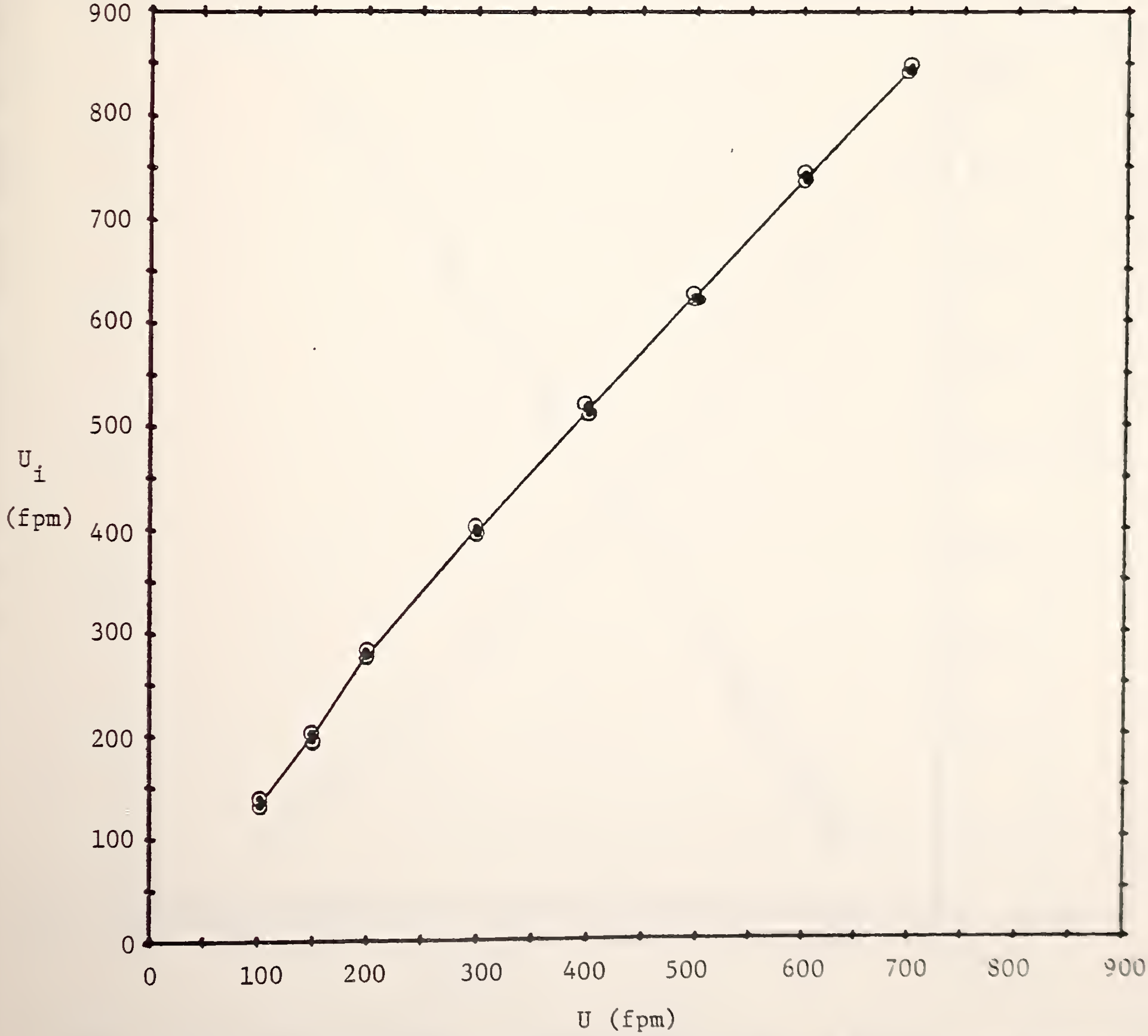


FIGURE 7. INDICATED VERSUS TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE.

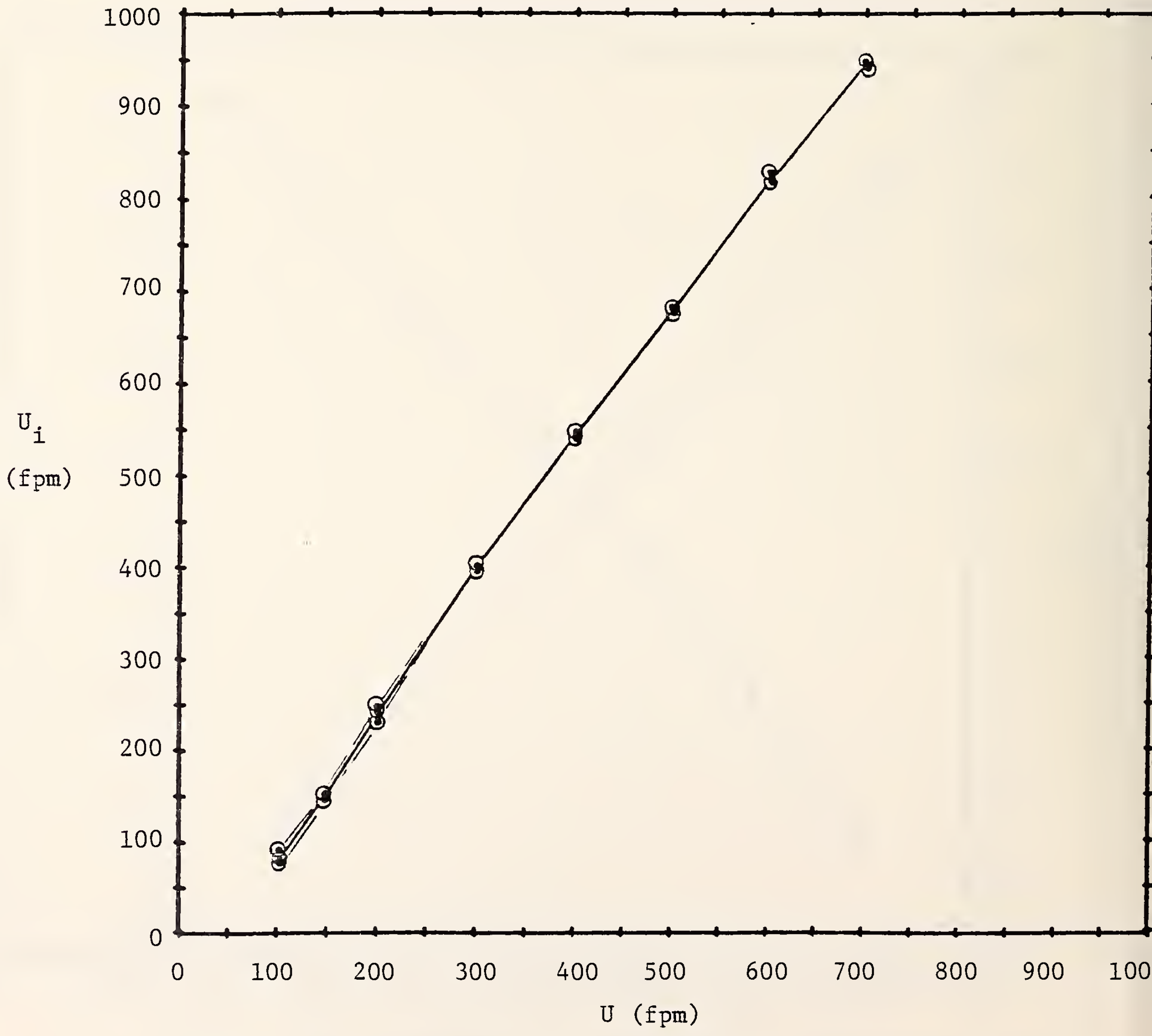


FIGURE 8. INDICATED VERSUS TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE.

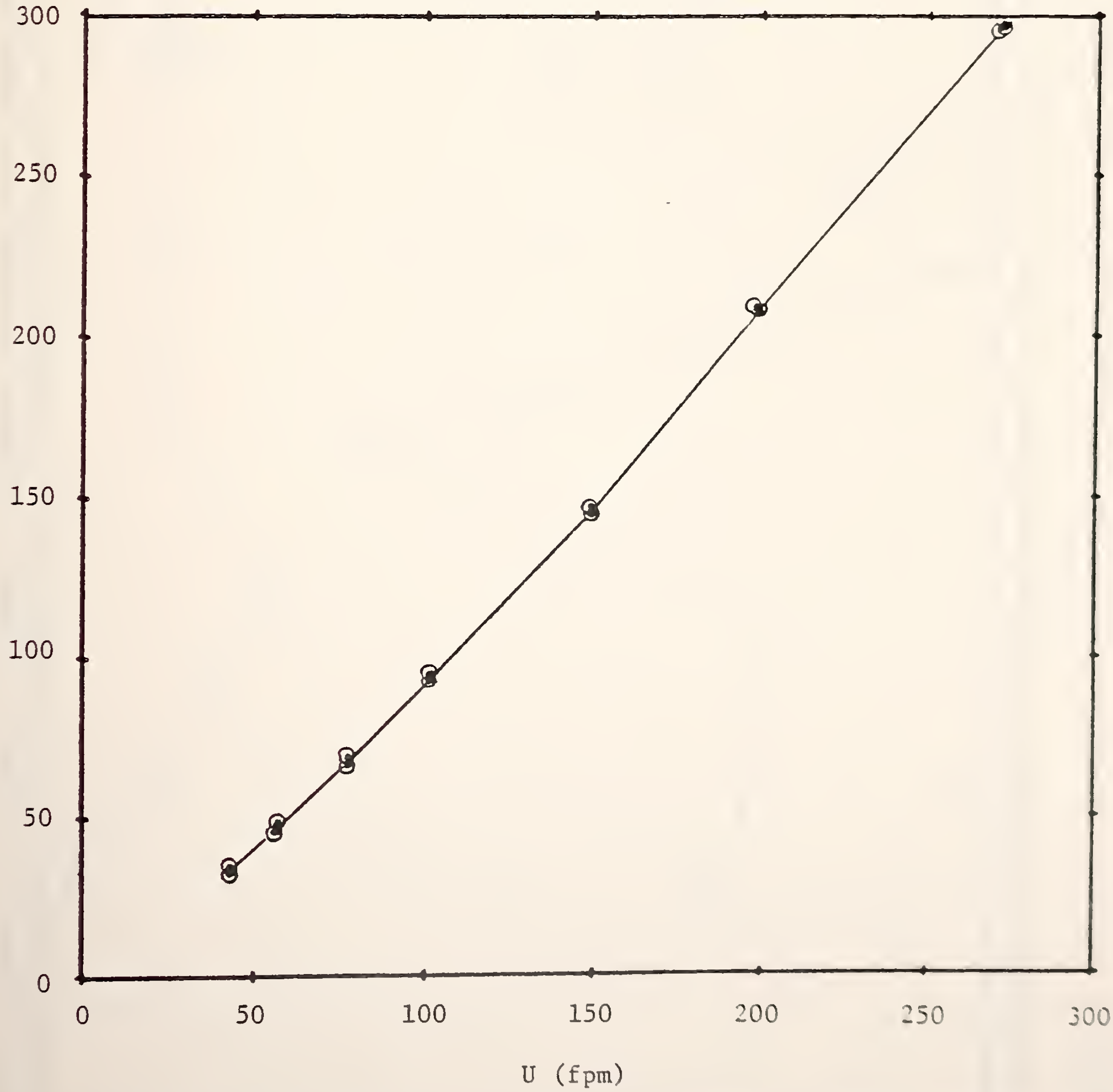


FIGURE 9. INDICATED VERSUS TRUE VELOCITY FOR LOW VELOCITY PROBE.

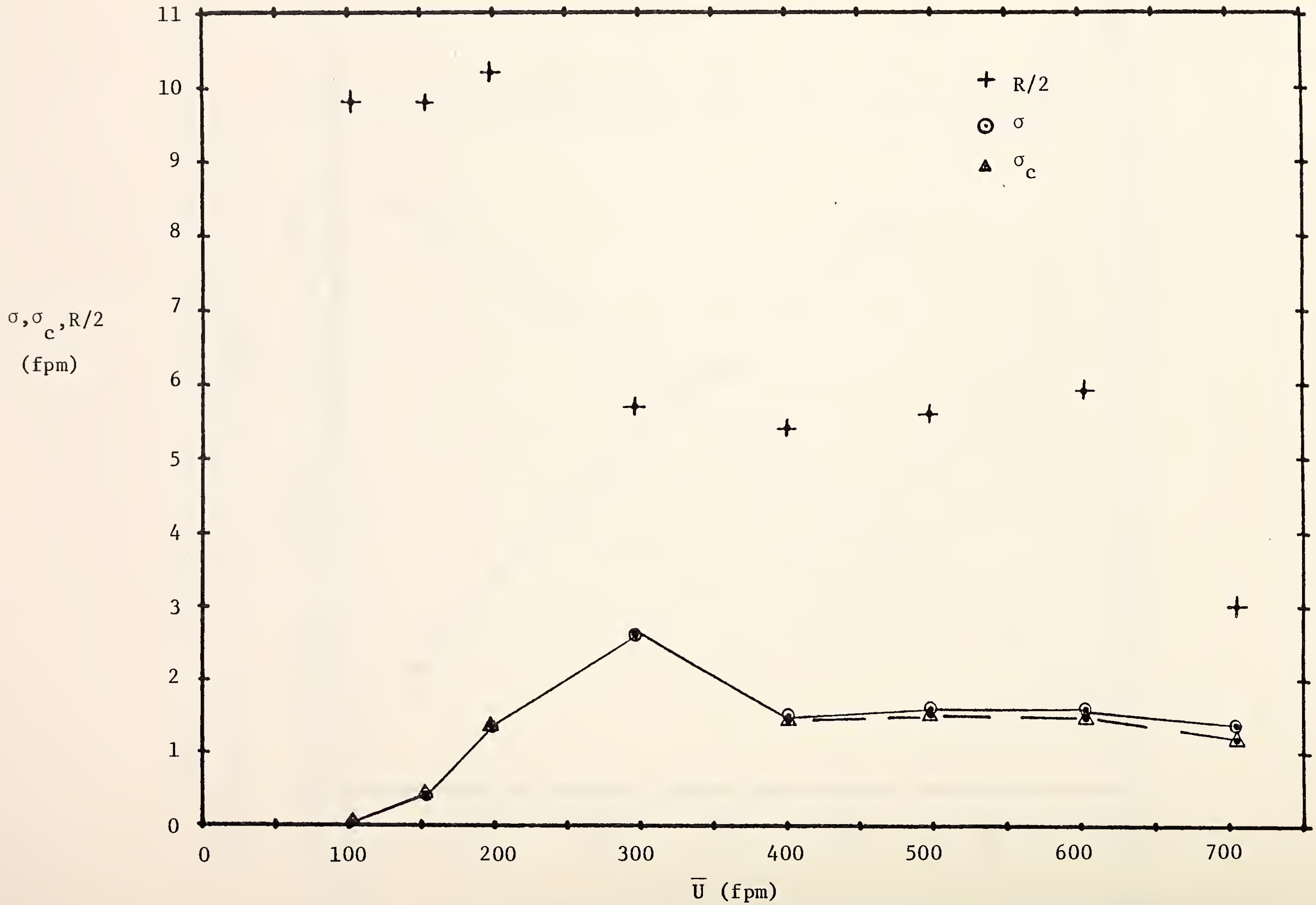


FIGURE 10. σ AND σ_c IN TERMS OF TRUE VELOCITY FOR PITOT PROBE, LOW RANGE. R/2 NOTED.

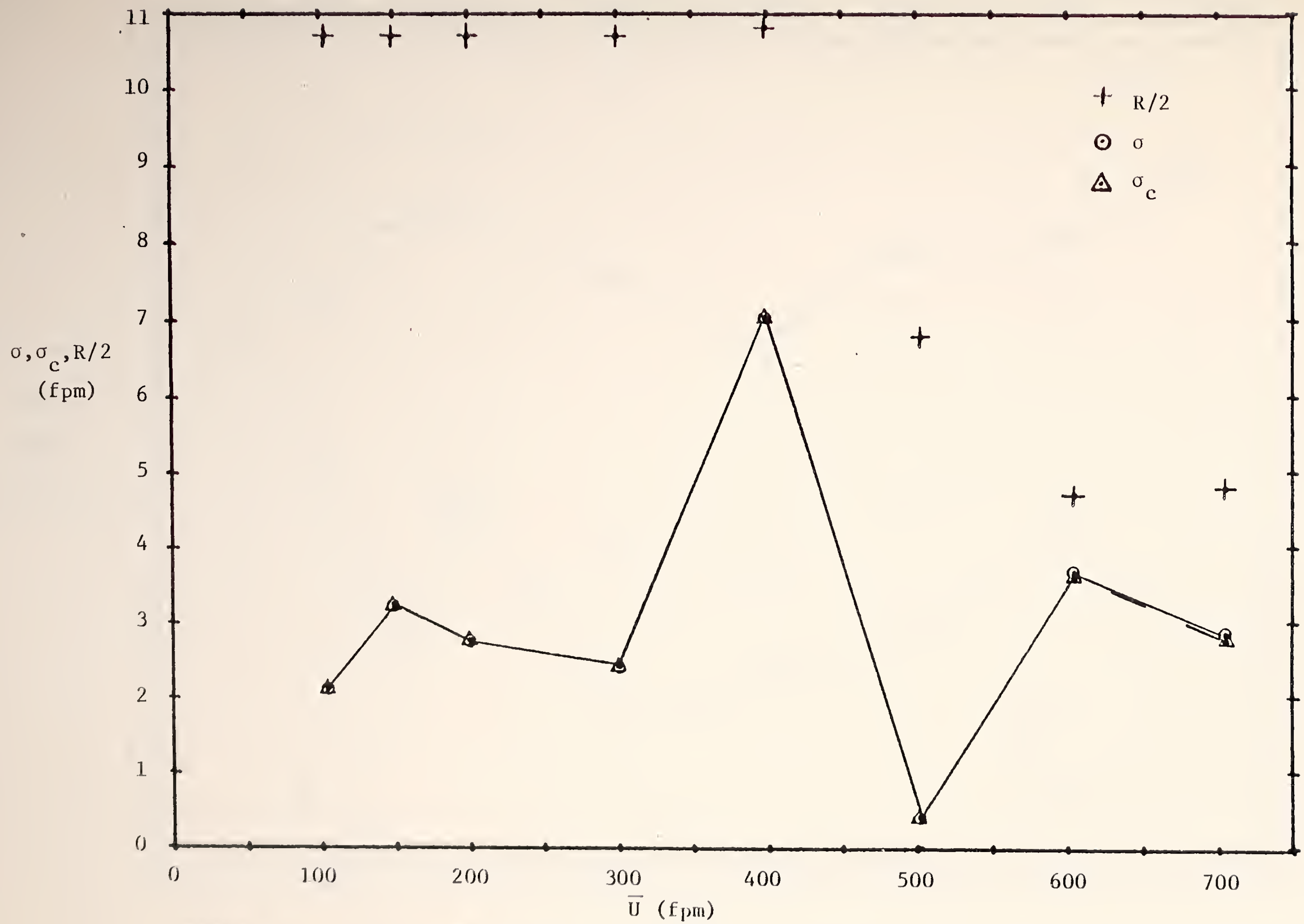


FIGURE 11. σ and σ_c IN TERMS OF TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE. R/2 NOTED.

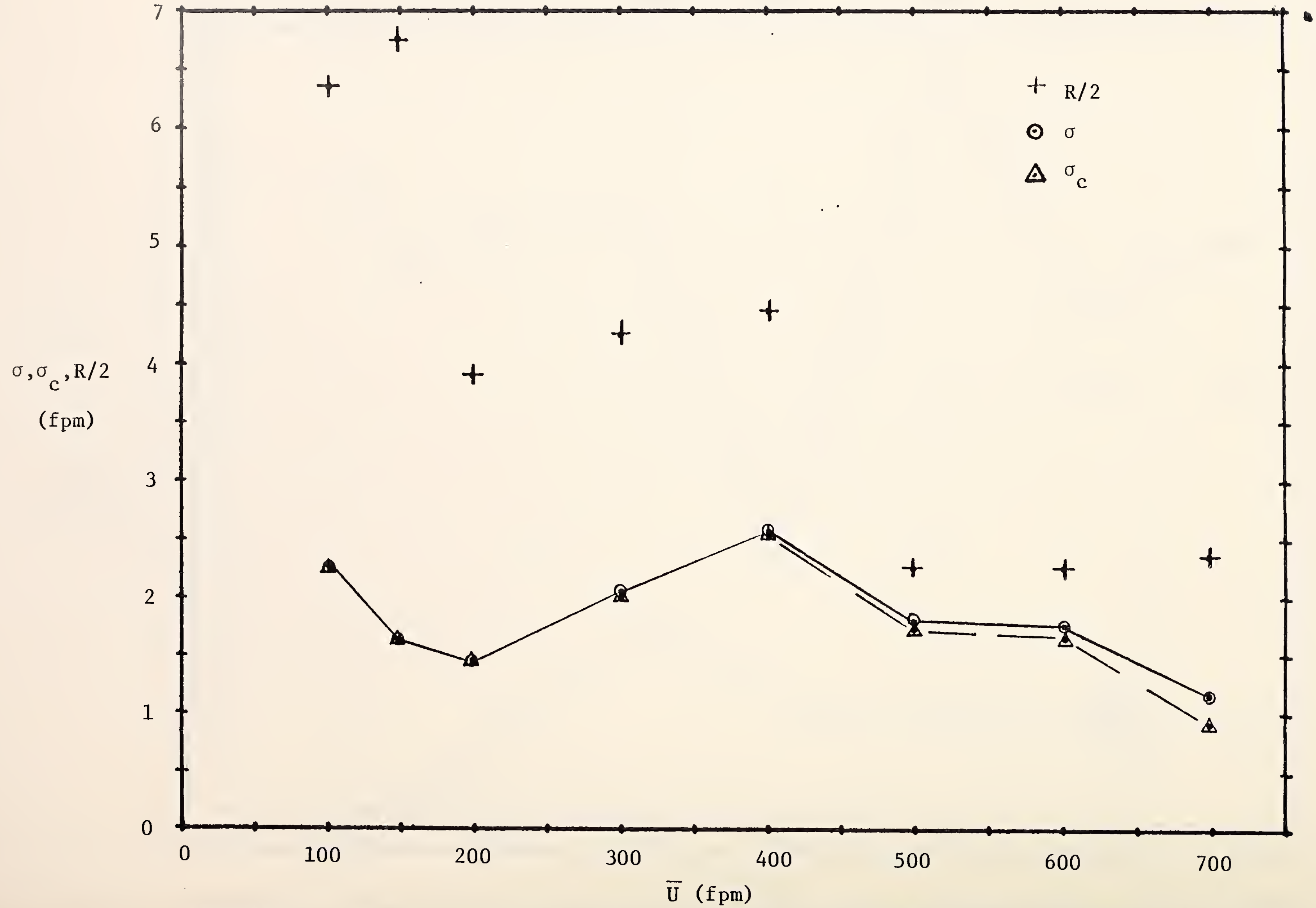


FIGURE 12. σ AND σ_c IN TERMS OF TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE. R/2 NOTED.

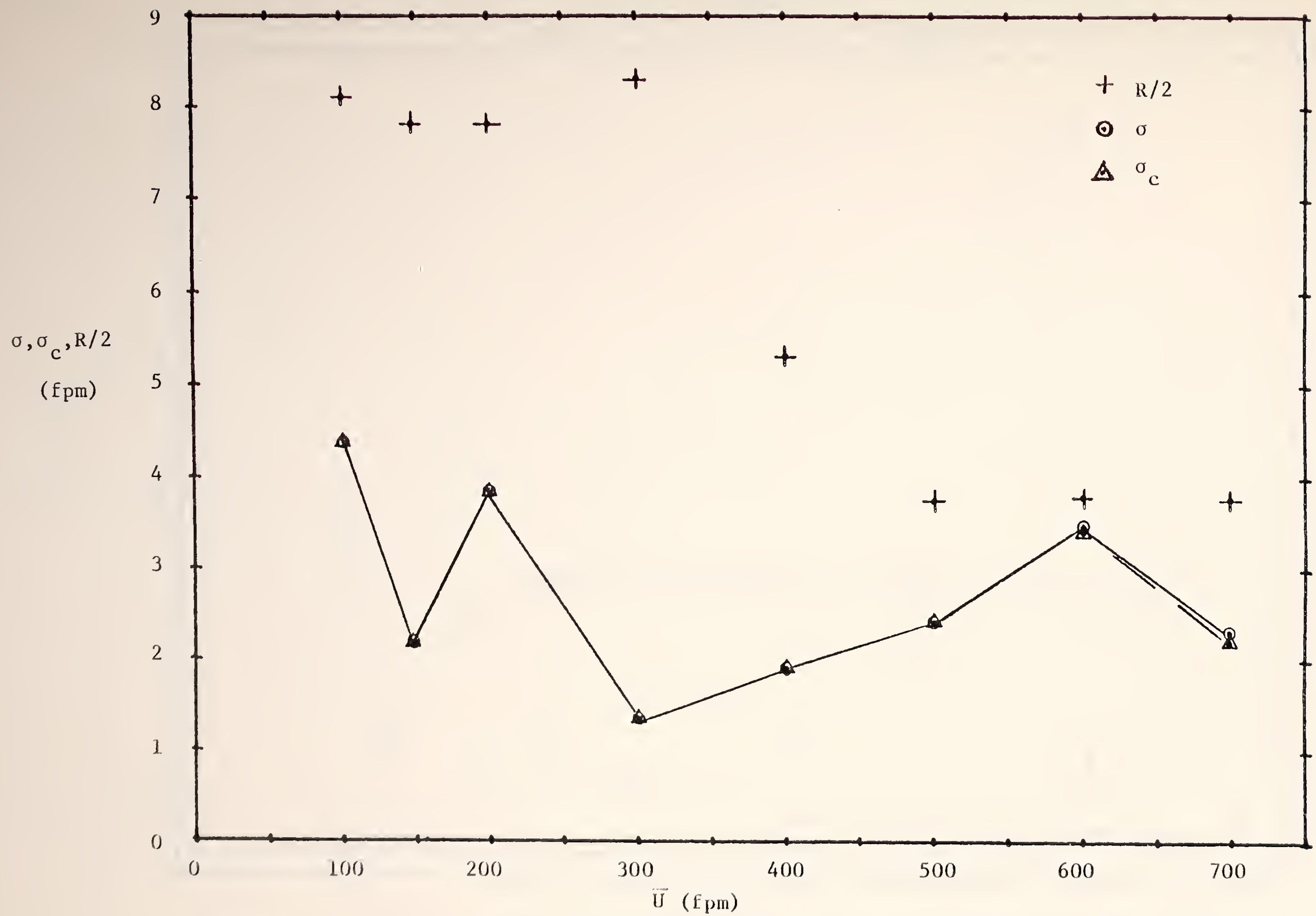


FIGURE 13. σ AND σ_c IN TERMS OF TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE. R/2 NOTED.

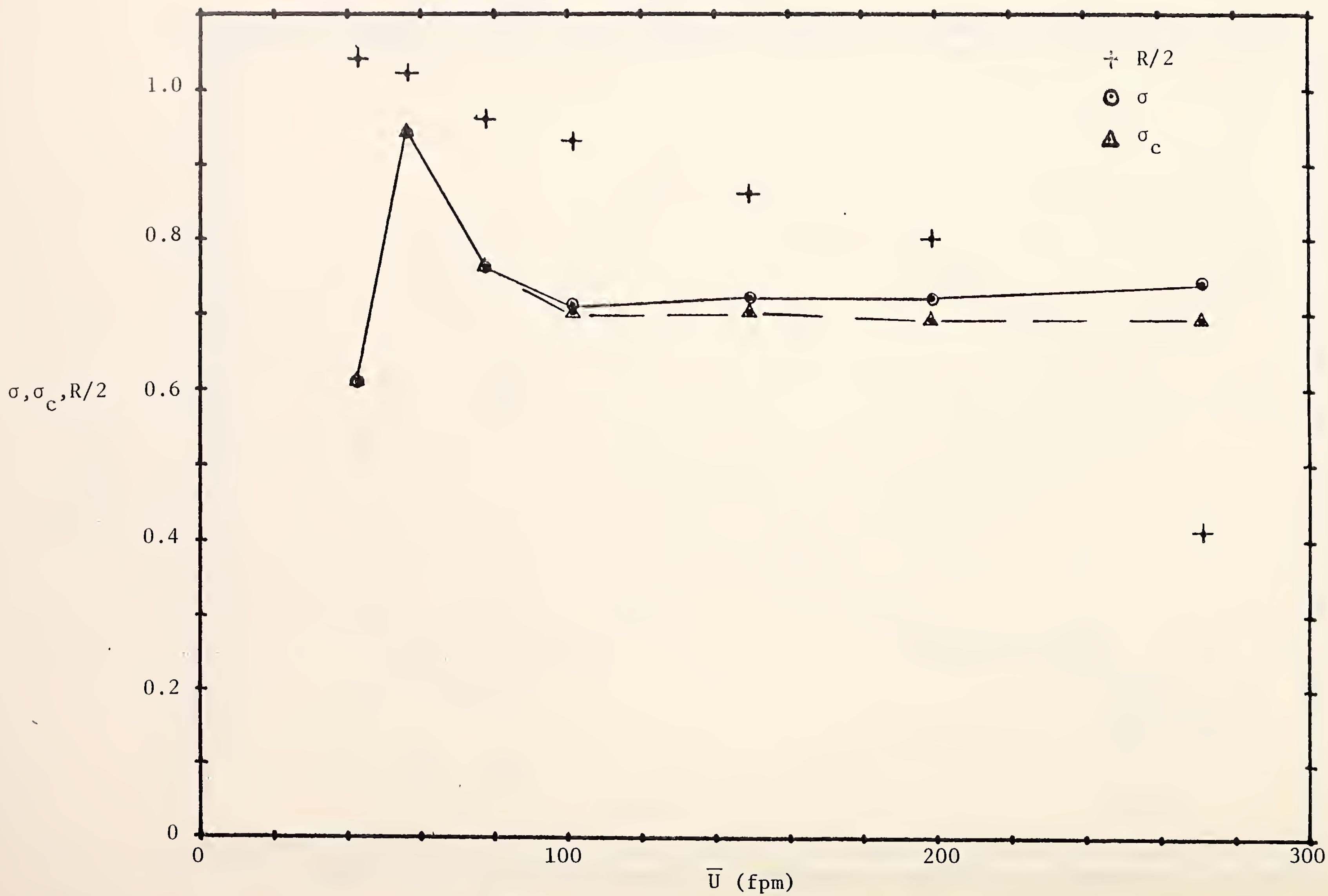


FIGURE 14. σ AND σ_c IN TERMS OF TRUE VELOCITY FOR LOW VELOCITY PROBE. R/2 NOTED.

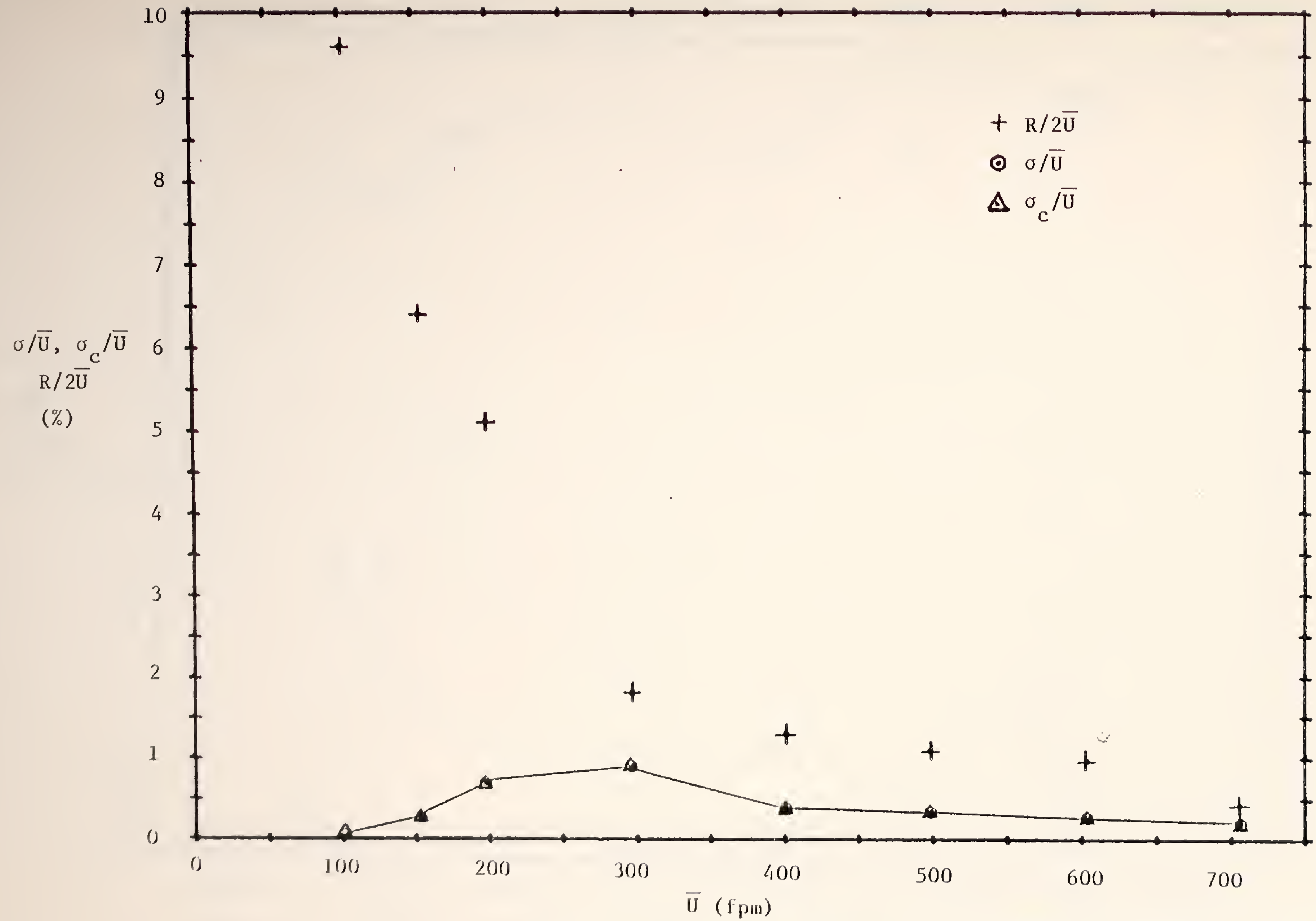


FIGURE 15. σ AND σ_c AS PERCENT OF GROUP MEAN VELOCITY FOR PITOT PROBE, LOW RANGE. $R/2\overline{U}$ NOTED.

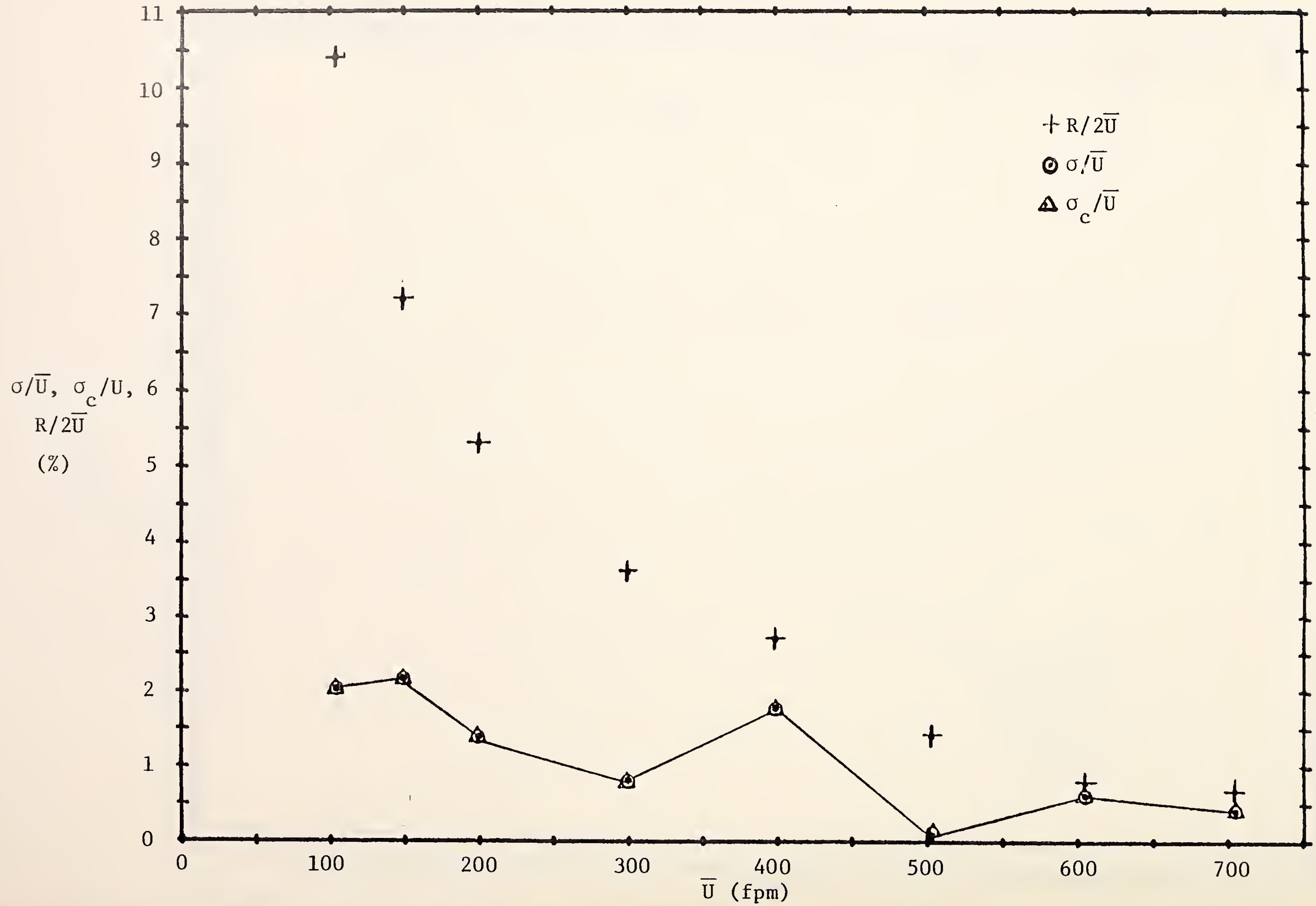


FIGURE 16. σ AND σ_c AS PERCENT OF GROUP MEAN VELOCITY FOR PITOT PROBE, HIGH RANGE. $R/2\overline{U}$ NOTED.

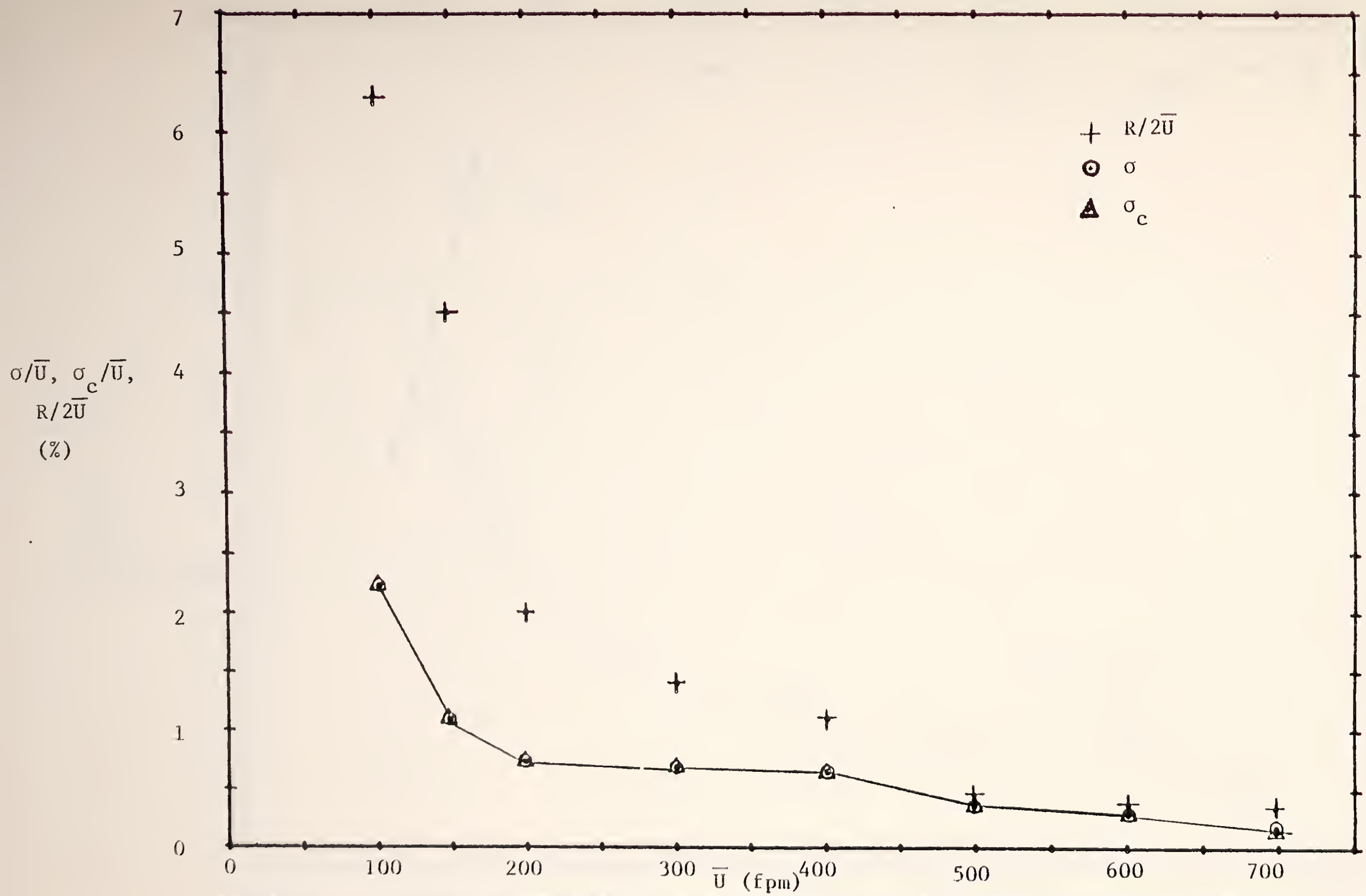


FIGURE 17. σ and σ_c AS PERCENT OF GROUP MEAN VELOCITY FOR DIFFUSER PROBE, LOW RANGE. $R/2\overline{U}$ NOTED.

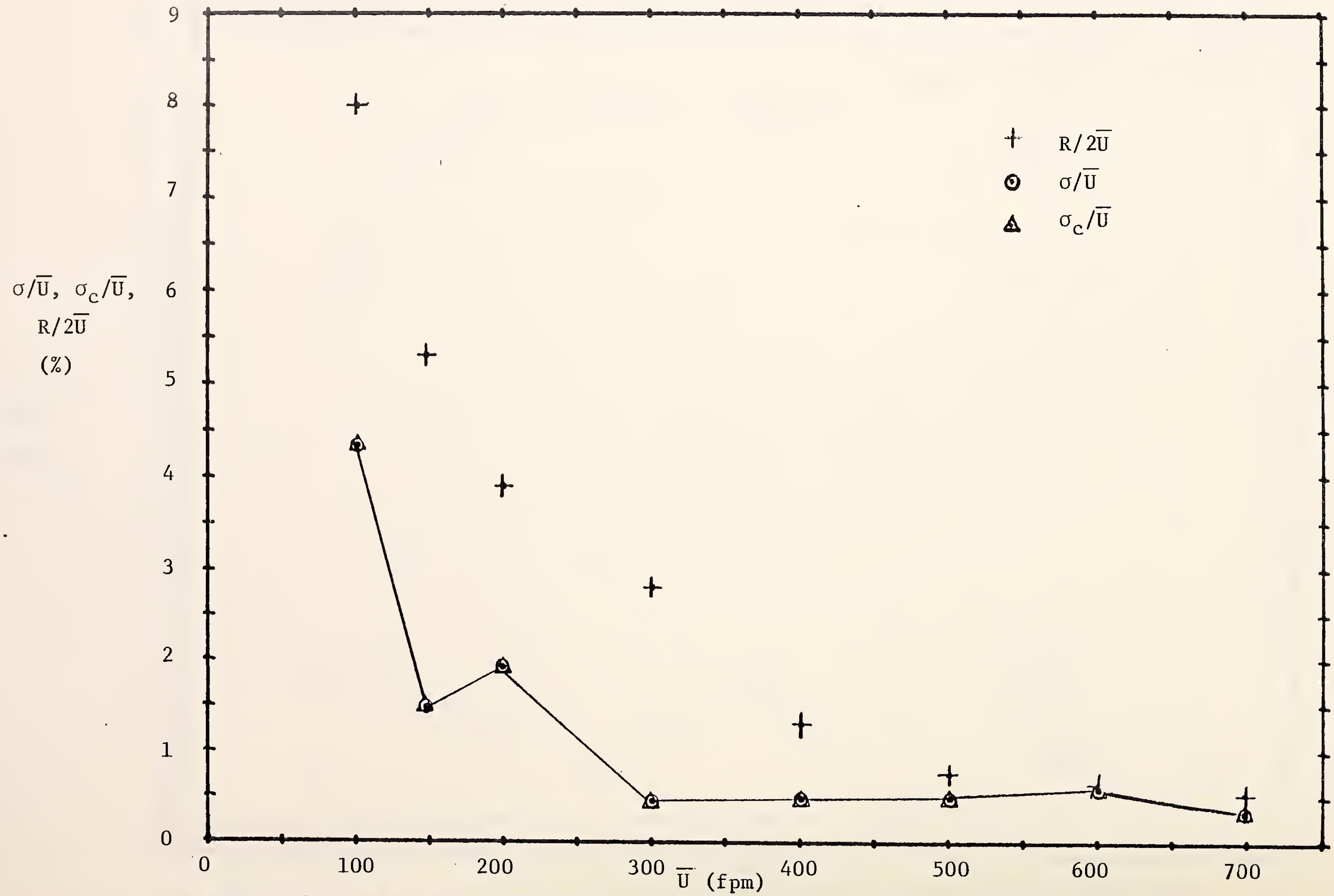


FIGURE 18. σ and σ_c AS PERCENT OF GROUP MEAN VELOCITY FOR DIFFUSER PROBE, HIGH RANGE. R/2U NOTED.

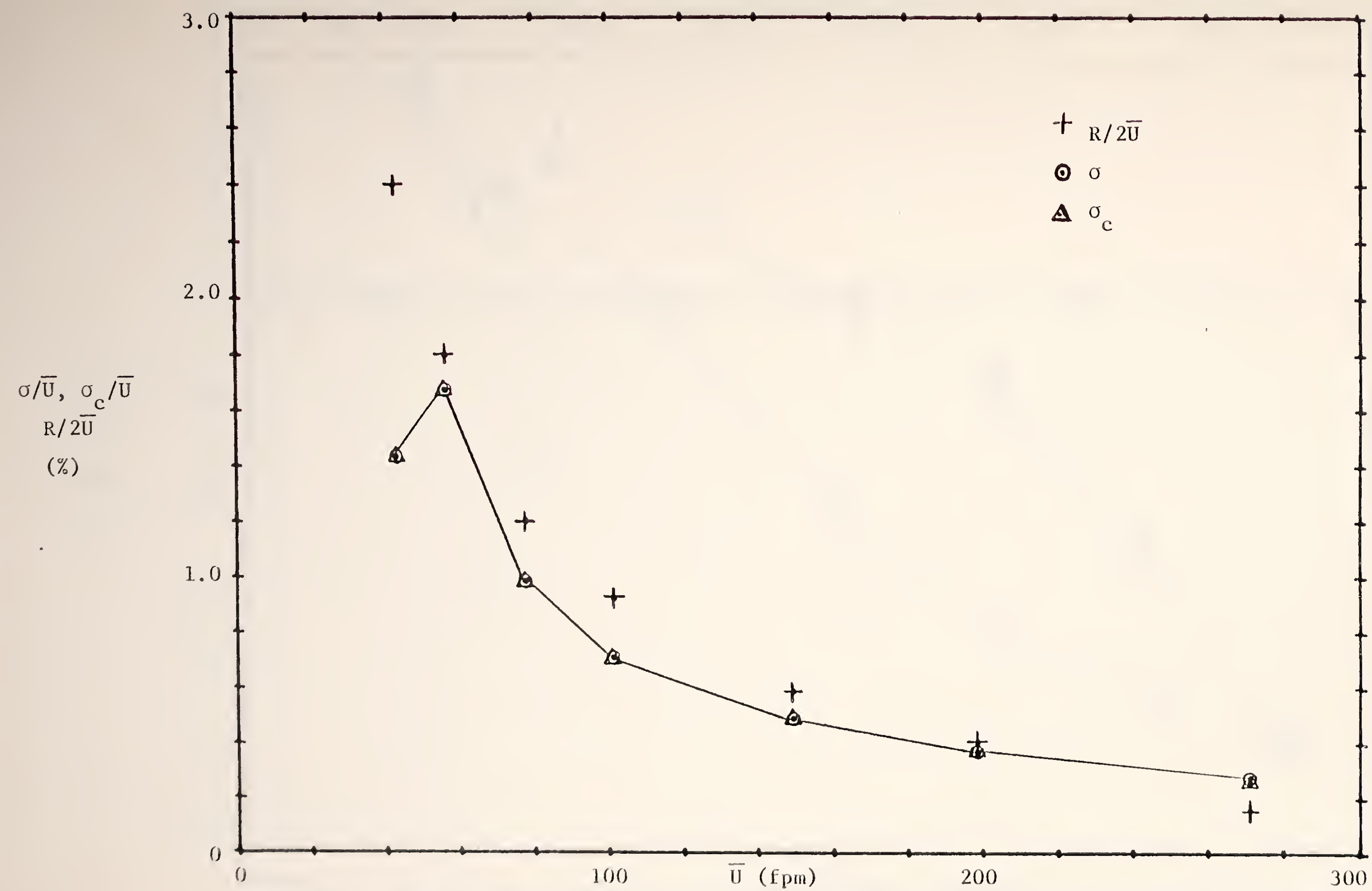


FIGURE 19. σ AND σ_c AS PERCENT OFGROUP MEAN VELOCITY FOR LOW VELOCITY PROBE. $R/2\overline{U}$ NOTED.

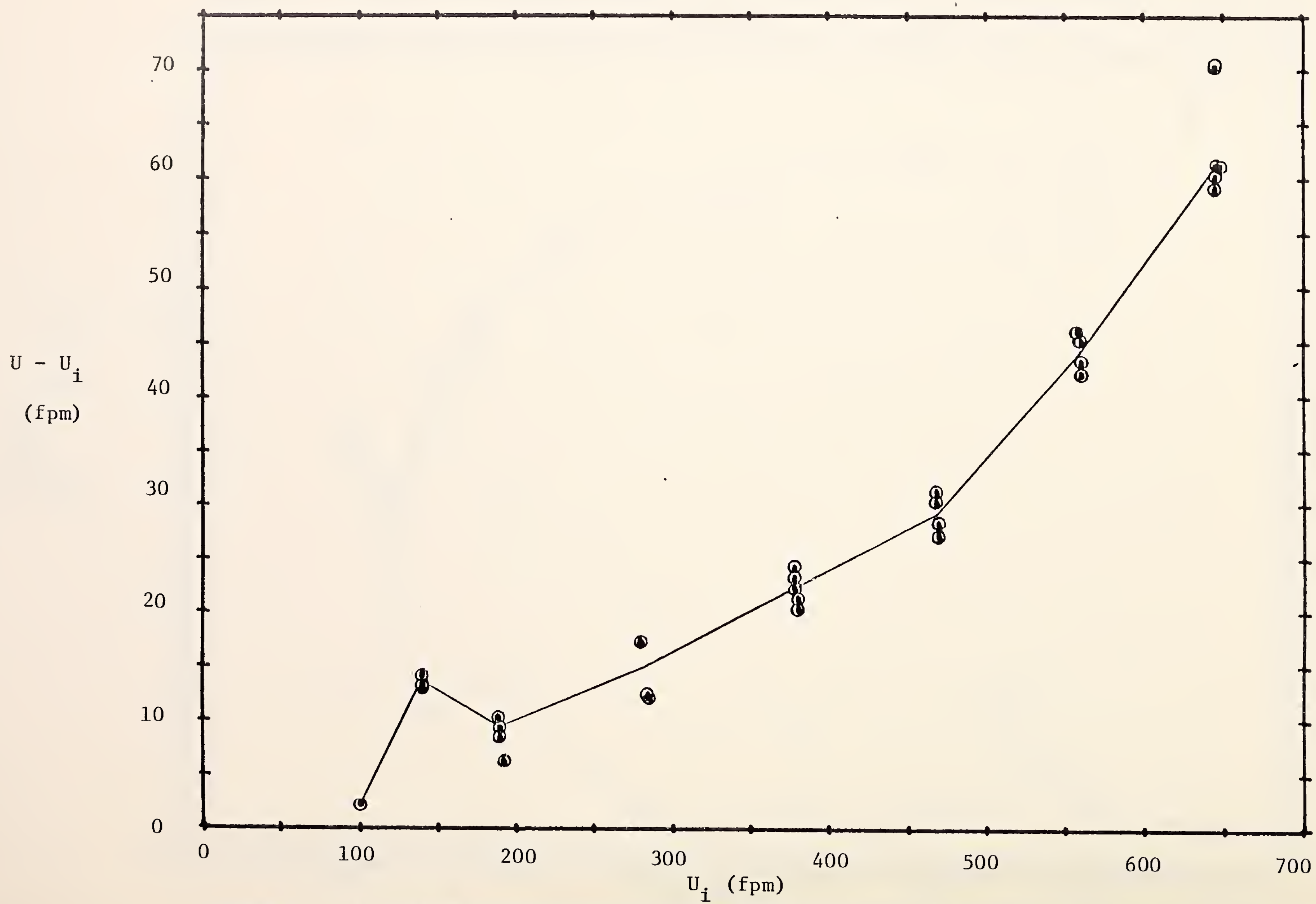


FIGURE 20. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR PITOT PROBE, LOW RANGE.

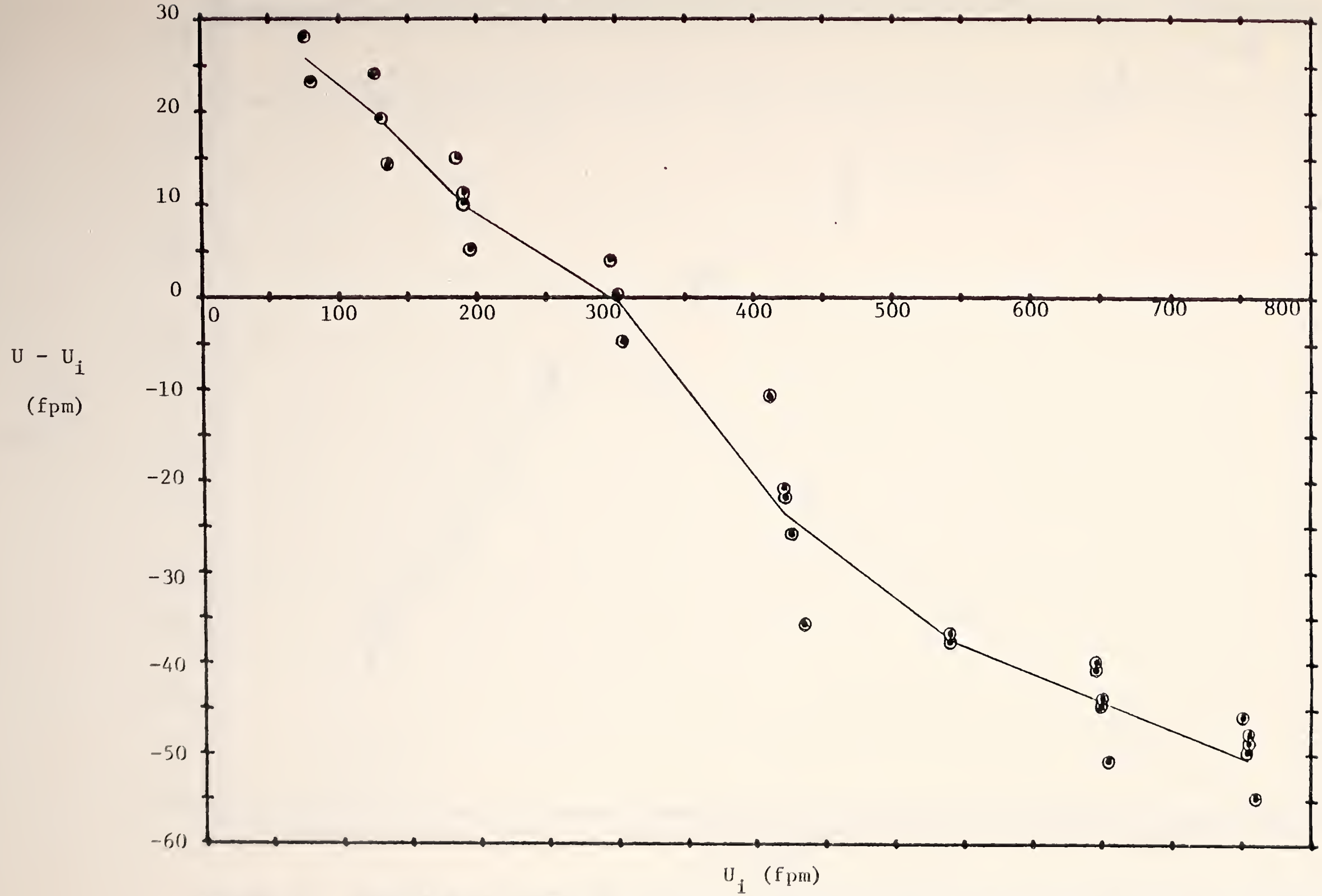


FIGURE 21. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE.

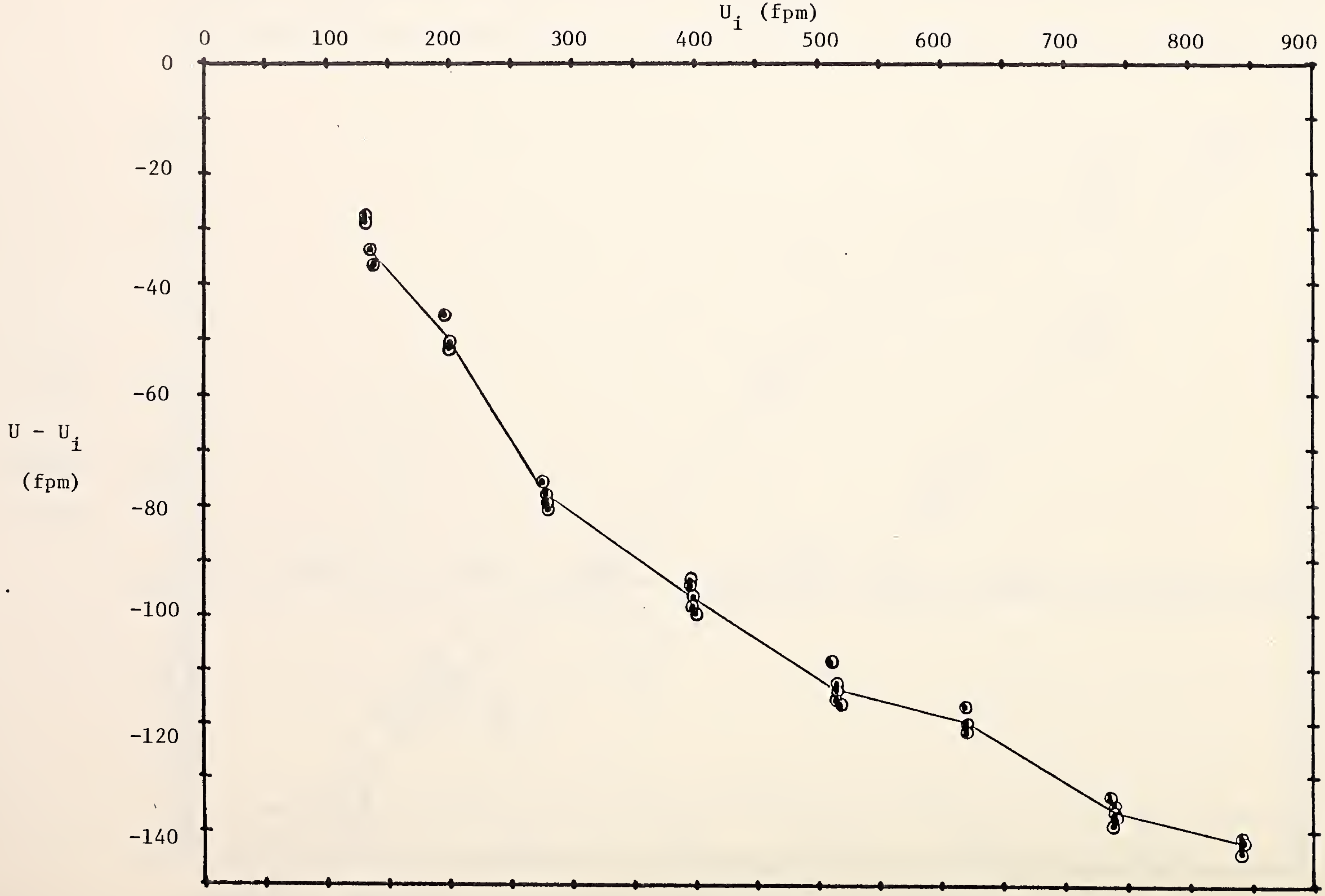


FIGURE 22. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE.

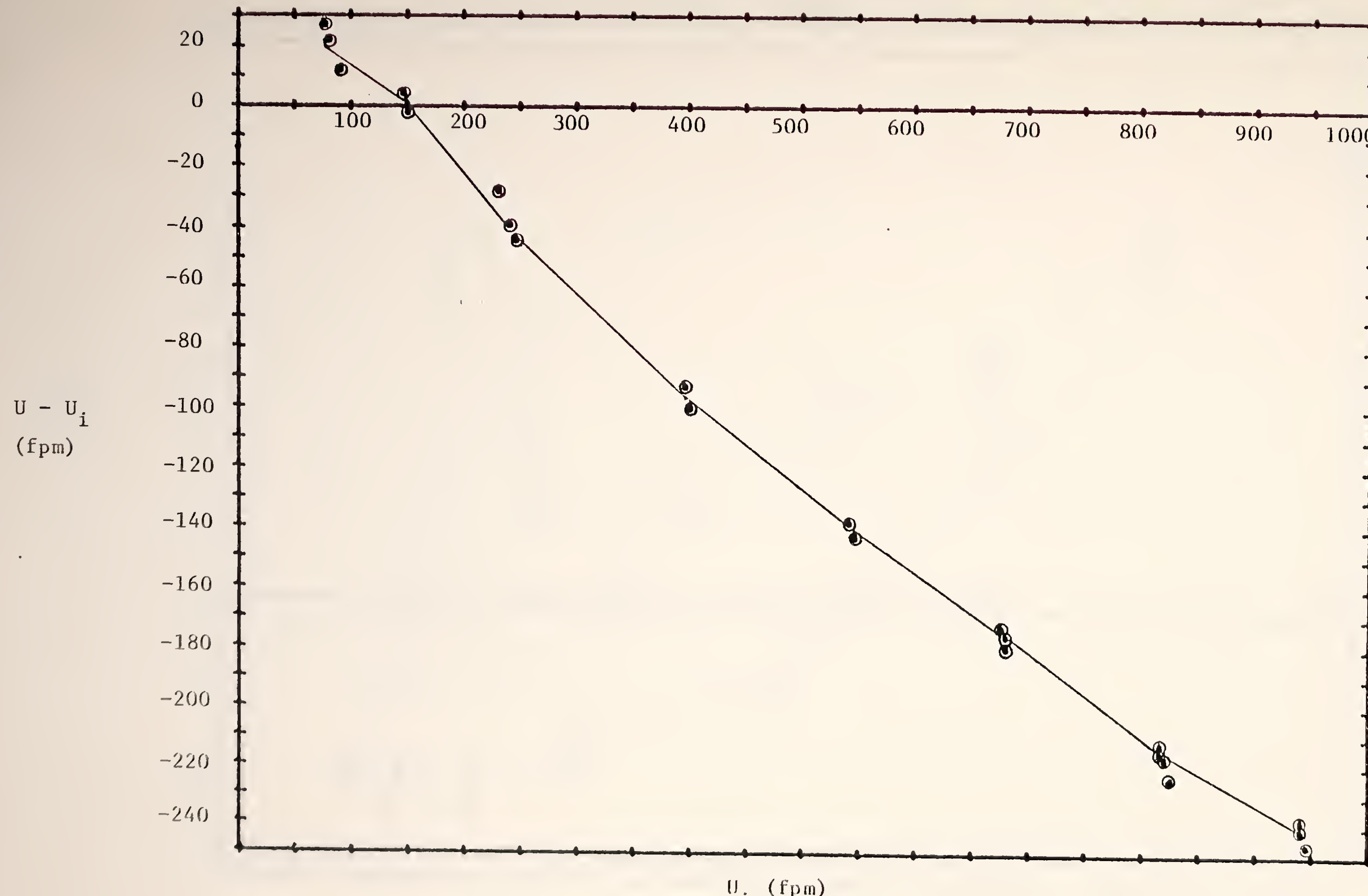


FIGURE 23. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE.

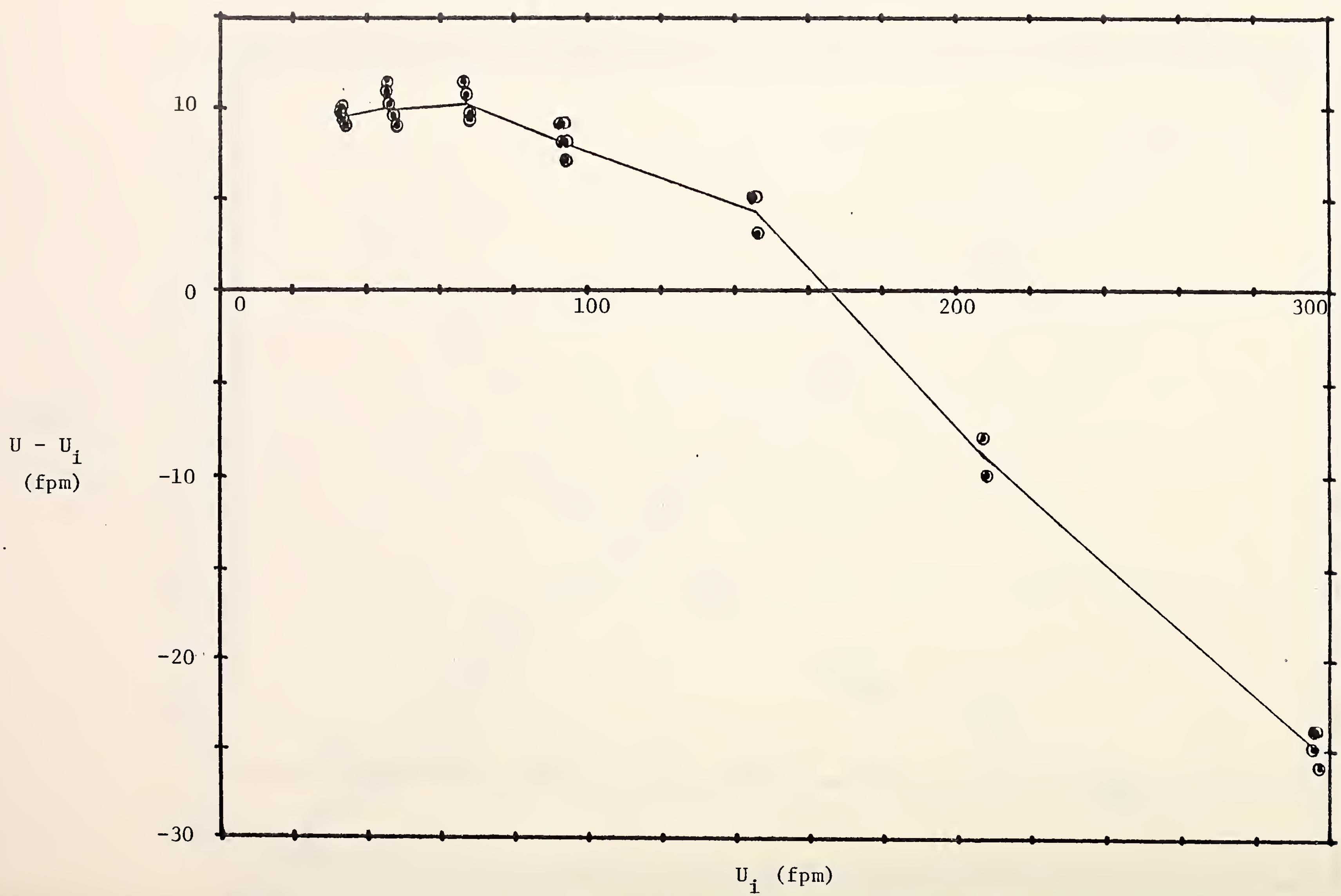


FIGURE 24. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR LOW VELOCITY PROBE.

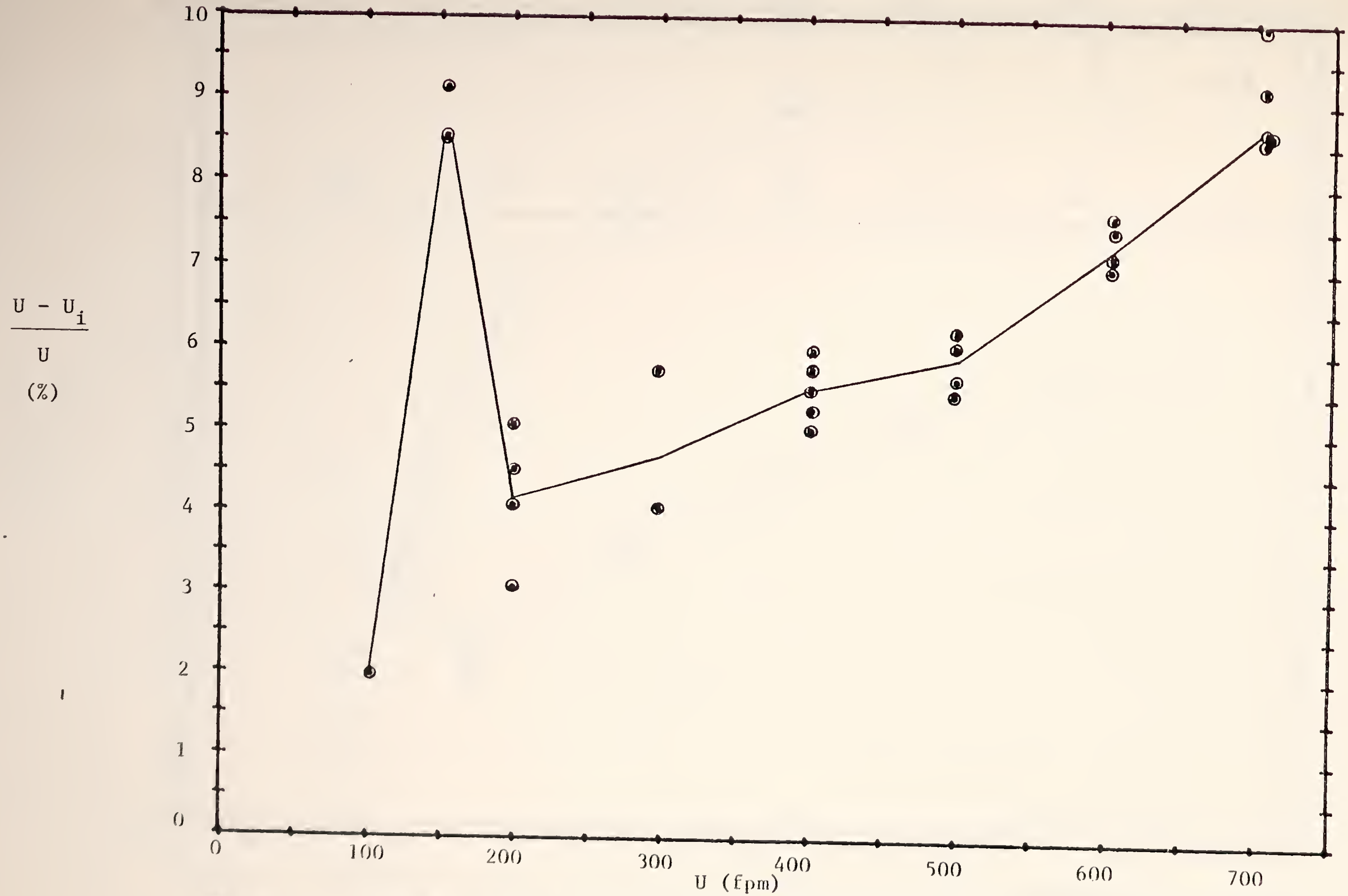


FIGURE 25. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR PITOT PROBE, LOW RANGE.

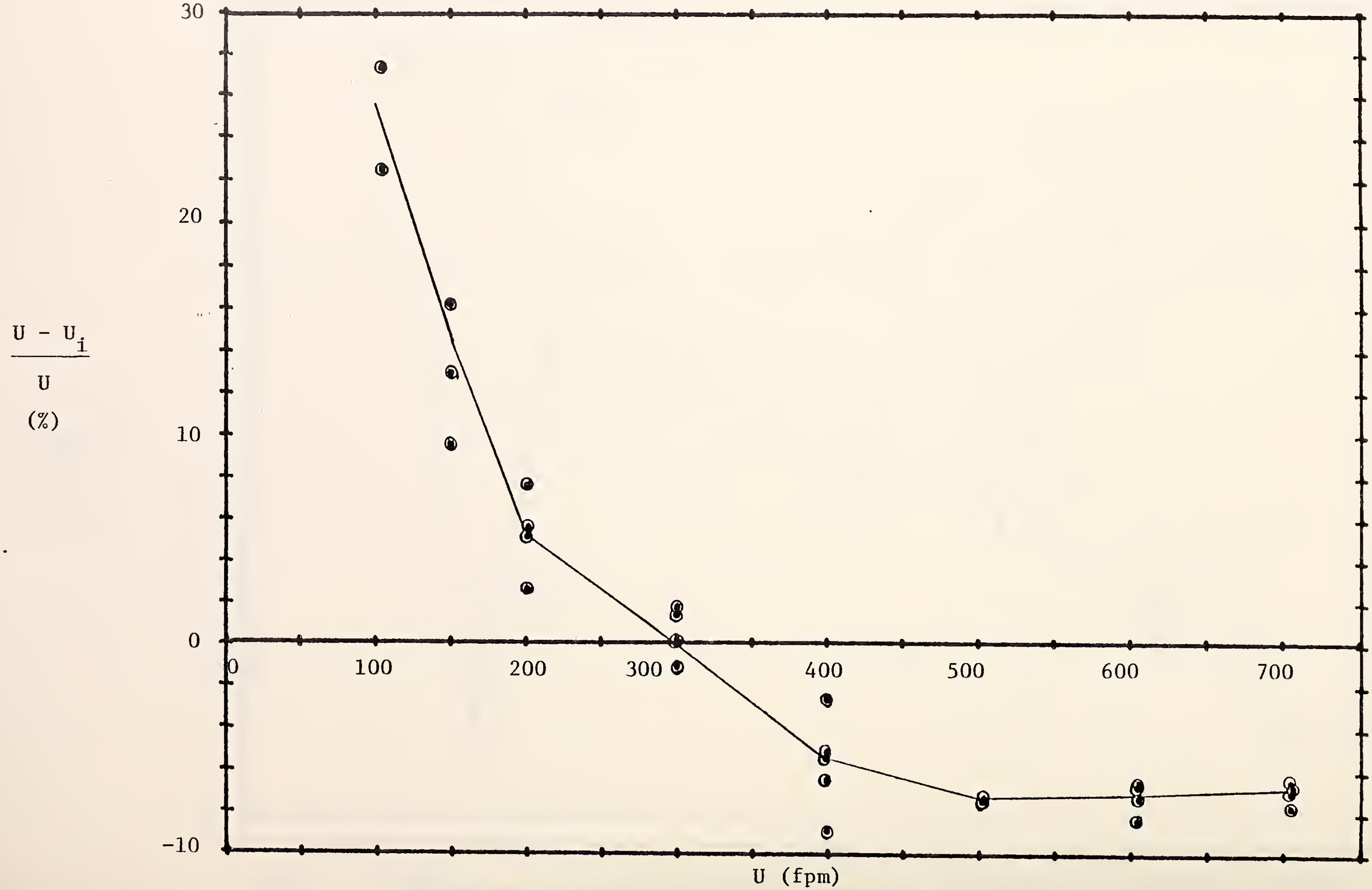


FIGURE 26. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE.

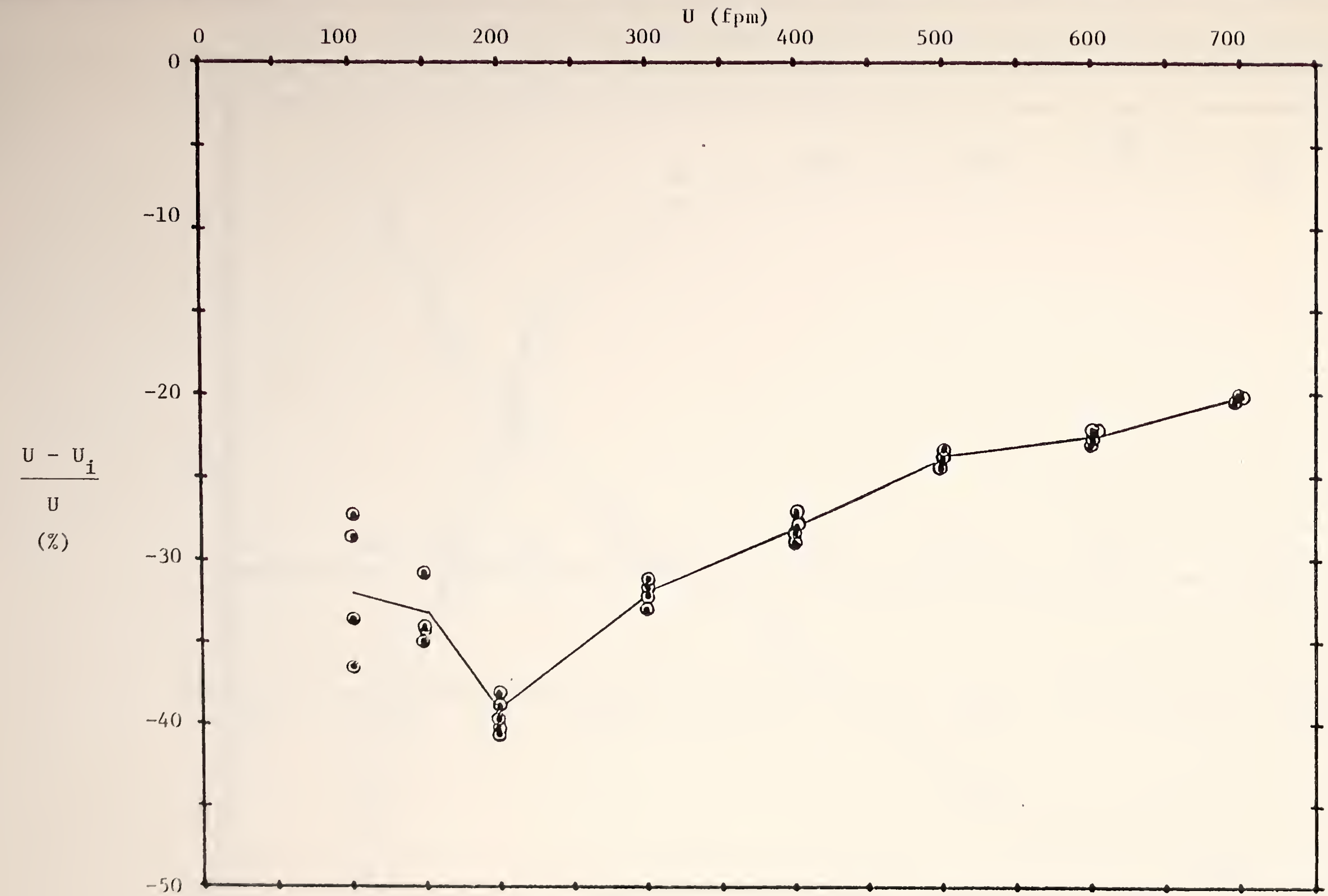


FIGURE 27. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE.

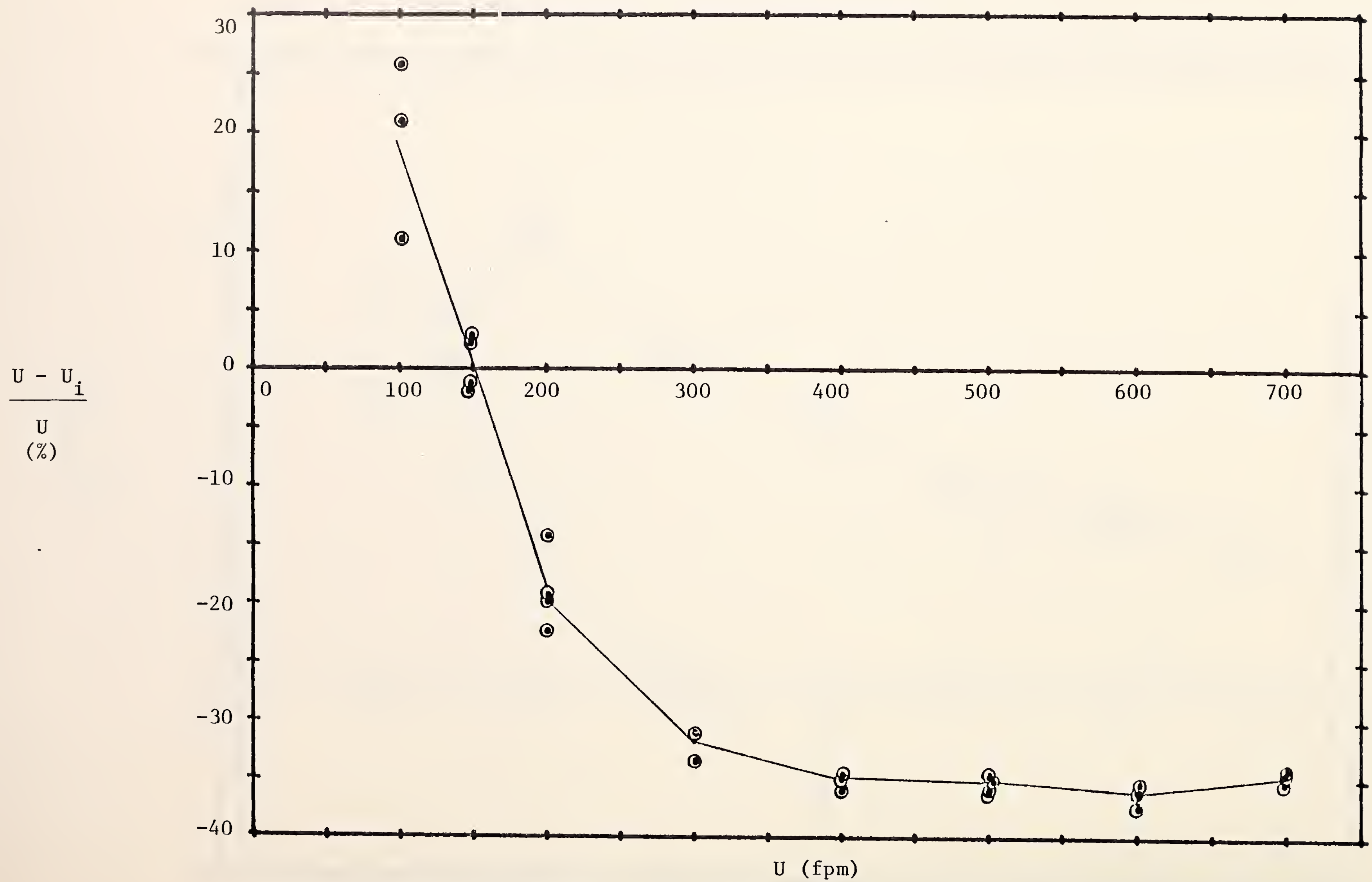


FIGURE 28. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE.

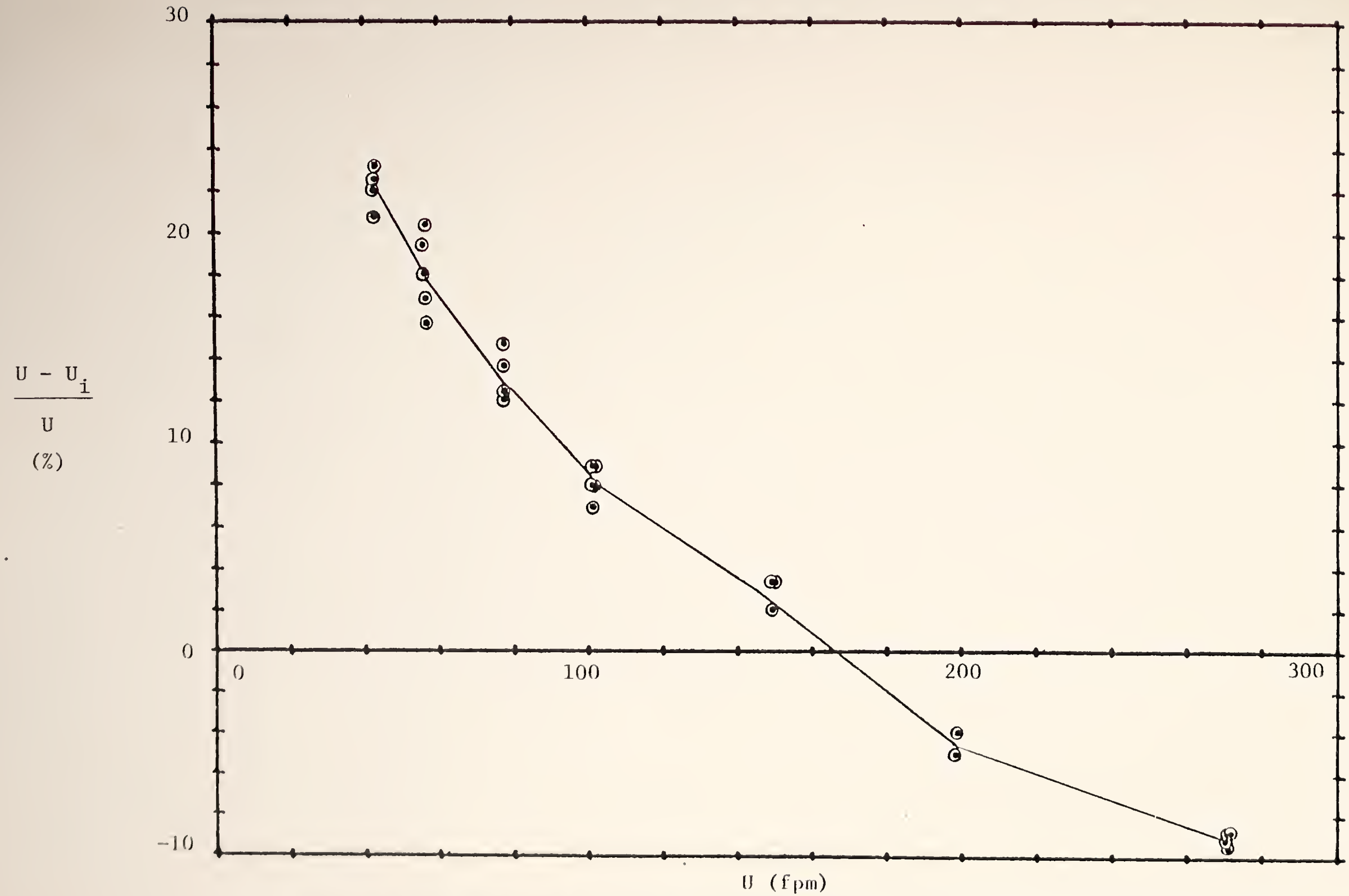


FIGURE 29. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR LOW VELOCITY PROBE.