
REPORT No. 264

**DIFFERENTIAL PRESSURES ON A PITOT-VENTURI
AND A PITOT-STATIC NOZZLE OVER
360° PITCH AND YAW**

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SUMMARY

Measurements of the differential pressures on two Navy air-speed nozzles, consisting of a Zahm type Pitot-Venturi tube and a SQ-16 two-pronged Pitot-static tube, in a tunnel air stream of fixed speed at various angles of pitch and yaw between 0° and $\pm 180^\circ$, show for a range over -20° to $+20^\circ$ pitch and yaw, indicated air speeds varying very slightly over 2 per cent for the Zahm type and a maximum of about 5 per cent for the SQ-16 type from the calibrated speed at 0°.

For both types of air-speed nozzle the indicated air speed increases slightly as the tubes are pitched or yawed several degrees from their normal 0° attitude, attains a maximum around $\pm 15^\circ$ to 25° , declines rapidly therefrom as $\pm 40^\circ$ is passed, to zero in the vicinity of $\pm 70^\circ$ to 100° , and thence fluctuates irregularly from thereabouts to $\pm 180^\circ$. The complete variation in indicated air speed for the two tubes over 360° pitch and yaw is graphically portrayed in Figures 9 and 10.

For the same air speed and 0° pitch and yaw the differential pressure of the Zahm type Pitot-Venturi nozzle is about seven times that of the SQ-16 type two-pronged Pitot-static nozzle.

INTRODUCTION

The data presented in this report were obtained in tests made for the Navy Bureau of Aeronautics at different times on a Zahm type and a SQ-16 type of air-speed nozzle in the 4 by 4 foot wind tunnel of the Bureau of Construction and Repair, Washington Navy Yard.

The present text and figures, submitted for publication to the National Advisory Committee for Aeronautics, November 29, 1926, have been compiled with some revision from C. & R. Aeronautical Reports Nos. 295 and 300 prepared by the aeronautics staff for the Bureau of Aeronautics.

Other N. A. C. A. reports on air-speed nozzles are Nos. 31, 110, 127, and 156. (References 1-4.)

DESCRIPTION OF NOZZLES

Photographs of the Zahm and SQ-16 air-speed nozzles mounted in the tunnel for testing constitute Figures 1, 2, 3, and 4, and drawings of the two nozzles with their chief dimensions are presented in Figures 5 and 6.

The Zahm Pitot-Venturi nozzles are manufactured by the American Instrument Company, of Washington, D. C.; the SQ-16 two-pronged Pitot-static nozzles, by the Pioneer Instrument Company, of Brooklyn, N. Y.

The two sample nozzles tested were stamped with the factory serial Nos. 1041 and 066239, respectively.

The Venturi of the Zahm type nozzle is made and assembled in three parts; namely, a short forward cone, a long trailing cone with spun trumpet flare, and an accurately reamed short cylinder connecting the two cones and forming the Venturi throat. The small boss visible

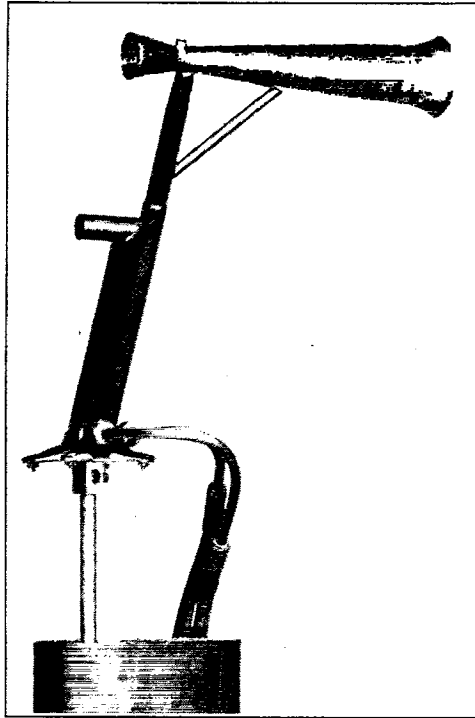


FIG. 1.—Zahm nozzle. Pitch mounting

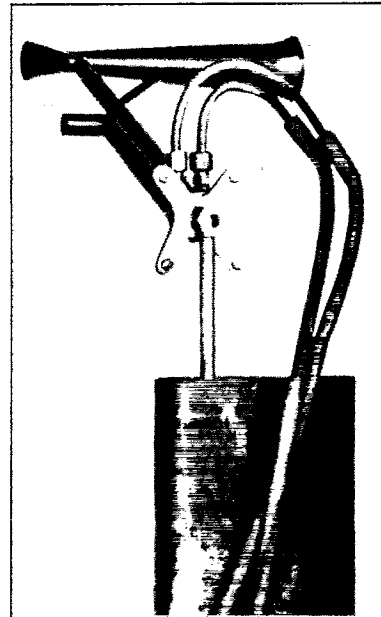


FIG. 2.—Zahm nozzle. Yaw mounting

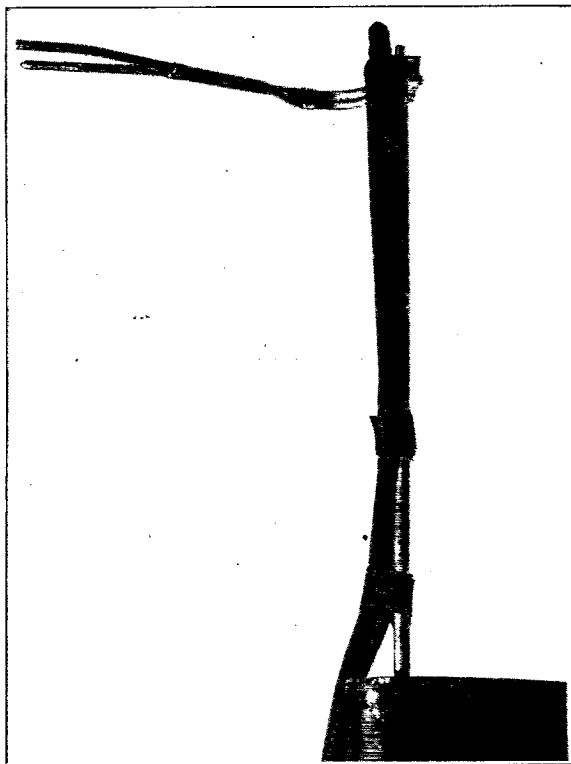


FIG. 3.—SQ-16 nozzle. Pitch mounting

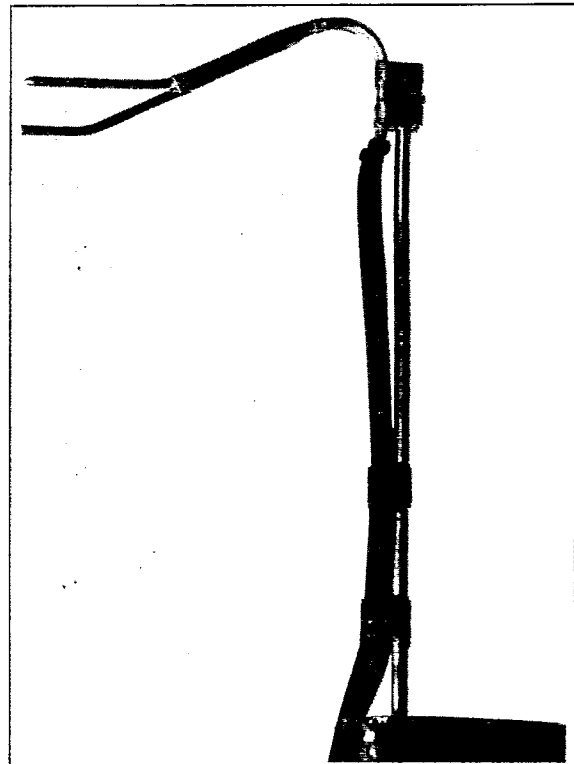


FIG. 4.—SQ-16 nozzle. Yaw mounting

in Figure 1 on the throat section opposite the Venturi duct, holds a standard 6-32 brass screw (fig. 5), which projects into the Venturi throat in the form of a 60° cone, slightly but uniformly truncated. By a slight adjustment of this screw in each of a given lot of nozzles it is possible to compensate for small factory variations in cone and throat dimensions causing variable differential pressures for the nozzles at the same air speed, and thus bring all into conformity with a standard calibration.

As seen from the illustrations of Figures 3 and 4, the SQ-16 Pitot-static nozzle differs essentially from an ordinary Pitot-static tube only in being shorter and having static and impact openings on separate prongs.

METHOD OF TESTS

In order that the nozzles could be rotated in both pitch and yaw on the vertical shaft of the wind tunnel balance, thereby facilitating accurate incidence setting, each of the two types was mounted on a small metal block, in which two three-eighths inch holes were drilled with axes at right angles to each other and to the nozzle axis. Thus fitted, the nozzle was mounted in the tunnel for testing on the end of a three-eighths-inch drill rod clamped in the balance-shaft chuck, as shown in Figures 1 to 4.

The nozzle incidences were set in the usual way for models, on the horizontal graduated plate encircling the balance shaft below the tunnel. All angular displacements of the nozzles were

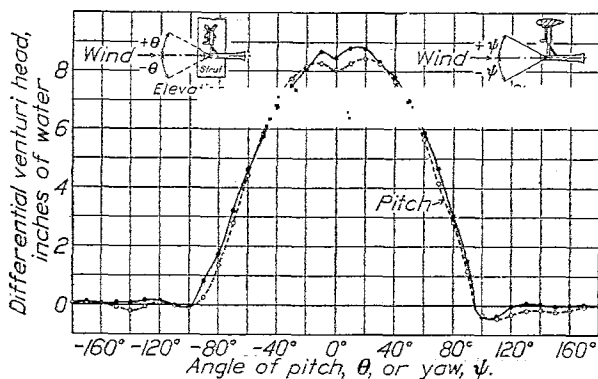


Fig. 7.—Zahm nozzle. Differential head versus angle of pitch or yaw at 50 M. P. H.

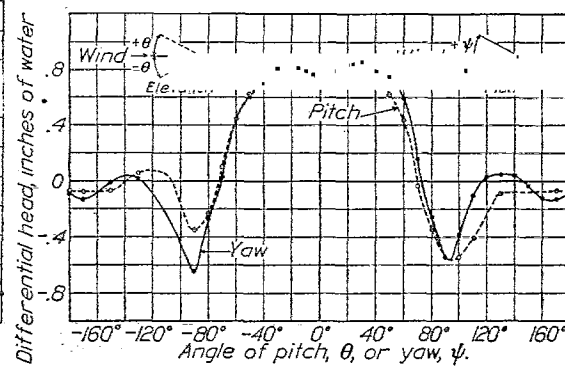


Fig. 8.—SQ-16 nozzle. Differential head versus angle of pitch or yaw at 40 M. P. H.

made in an air stream of fixed test speed, and with a sequence of incidence settings progressing from 0° to -180° and 0° to +180°.

The test speed for the Zahm nozzle was 50 miles an hour; for the SQ-16 40 miles an hour.

The differential pressure heads were read on an inclined alcohol manometer fixed below the tunnel at such a slope as to indicate pressures directly in inches of water.

RESULTS OF TESTS

Tables I and II give the observed differential heads in vertical inches of water for the two nozzles in both pitch and yaw, and Figures 7 and 8 portray these same data graphically.

The discrepancy in the observed differential pressures on the Zahm nozzle for the pitch and yaw mountings at 0° is probably due to the fact that the nozzle occupied different positions in the tunnel for the two mountings, and was thus possibly subjected to different types of air flow or interference effects.

Differential pressures observed on the Zahm nozzle with the calibration set-screw cone removed from the Venturi throat give a pressure versus incidence curve for -20° to +20° yaw and pitch, having less depression near the center than the curves of Figure 7.

Table III gives comparative data for the two types of nozzle in the form of velocity ratios or "correction factors," based on the 0° pitch and yaw differential pressure heads. These data are plotted for graphical comparison in Figures 9 and 10.

Assuming the indicated velocity V to vary as the square root of the nozzle differential pressure, the factor K , tabulated and plotted, is defined as follows:

$$K = \frac{V \text{ at pitch, } \theta^\circ, \text{ yaw } 0^\circ; \text{ or yaw } \psi^\circ, \text{ pitch } 0^\circ}{V \text{ at } 0^\circ \text{ pitch and yaw}}$$

In the above form, K always has small finite values, which are hence better adapted for comparative plotting over the complete test range, than the larger values obtained at high angles

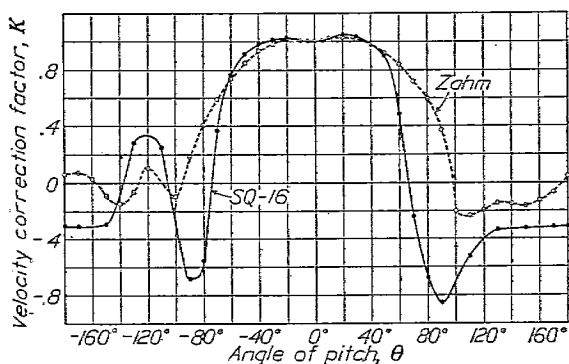


Fig. 9.—Velocity correction factor versus angle of pitch

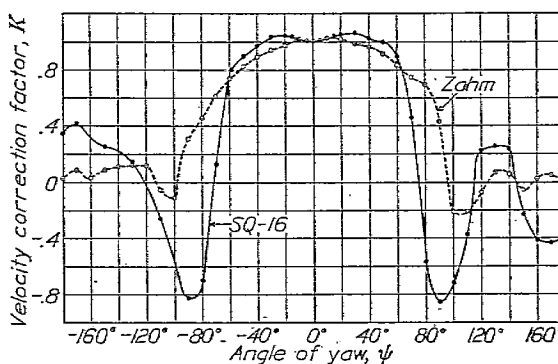


Fig. 10.—Velocity correction factor versus angle of yaw

from the inverse relation. The reciprocal $1/K$, however, is more convenient for use, as a multiplier, in the conversion of the indicated speed to the true one, and hence is given in Table IV for all angles of the test, and plotted in Figure 11 for a limited but ample range of pitch and yaw angles, including the practical flying attitudes. The percentage correction to be added algebraically to the indicated speed to obtain the true value is also here clearly shown for any practical nozzle attitude.

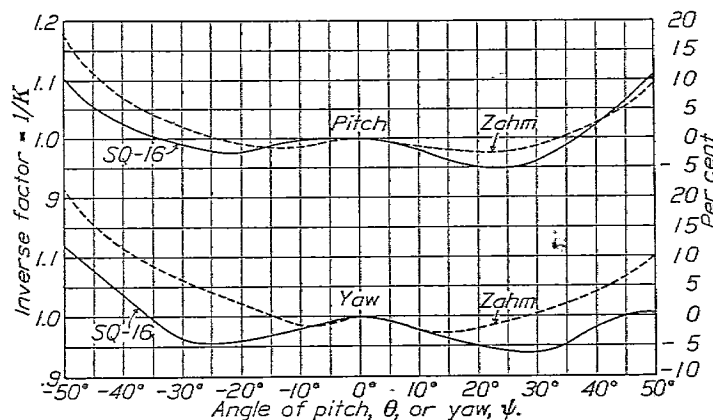


Fig. 11.—Inverse factor versus angles of pitch and yaw

REFERENCES

1. National Advisory Committee for Aeronautics. Development of Air-Speed Nozzles. N. A. C. A. Technical Report No. 31, 1919.
2. National Advisory Committee for Aeronautics. The Altitude Effect on Air-Speed Indicators. N. A. C. A. Technical Report No. 110, 1920.
3. National Advisory Committee for Aeronautics. Aircraft Speed Instruments. N. A. C. A. Technical Report No. 127, 1921.
4. National Advisory Committee for Aeronautics. The Altitude Effect on Air-Speed Indicators—II. N. A. C. A. Technical Report No. 156, 1922.

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TABLE I

DIFFERENTIAL HEAD ON ZAHM NOZZLE AT 50 M. P. H.

| Angle of pitch or yaw (degrees) | Differential head ¹ (inches of water) | | Angle of pitch or yaw (degrees) | Differential head ¹ (inches of water) | |
|---------------------------------|--|----------------|---------------------------------|--|----------------|
| | Nozzle yawed | Nozzle pitched | | Nozzle yawed | Nozzle pitched |
| 0 | +8.43 | +8.03 | 0 | +8.40 | +8.02 |
| +10 | 8.80 | 8.23 | -10 | 8.67 | 8.23 |
| 20 | 8.77 | 8.41 | -20 | 8.07 | 8.17 |
| 30 | 8.27 | 8.23 | -30 | 7.48 | 7.71 |
| 40 | 7.81 | 7.64 | -40 | 6.77 | 7.00 |
| 50 | 6.96 | 6.71 | -50 | 5.72 | 5.78 |
| 60 | 5.87 | 5.64 | -60 | 4.60 | 4.40 |
| 70 | 4.63 | 4.13 | -70 | 3.22 | 2.78 |
| 80 | 3.02 | 2.83 | -80 | 1.75 | 1.31 |
| 90 | +1.51 | +1.13 | -90 | +0.84 | +0.28 |
| 100 | -0.39 | -0.32 | -100 | -0.09 | -0.08 |
| 110 | -0.34 | -0.42 | -110 | -0.02 | 0.00 |
| 120 | -0.04 | -0.30 | -120 | +0.13 | +0.09 |
| 130 | +0.05 | -0.16 | -130 | 0.13 | -0.03 |
| 140 | +0.04 | -0.16 | -140 | 0.09 | -0.19 |
| 150 | -0.02 | -0.21 | -150 | 0.08 | -0.07 |
| 160 | +0.01 | -0.12 | -160 | 0.01 | +0.01 |
| 170 | +0.03 | -0.03 | -170 | 0.08 | 0.05 |
| +180 | 0.00 | +0.02 | -180 | +0.01 | +0.03 |

¹ Tabulated differential head is mean of 10 readings

TABLE II

DIFFERENTIAL HEAD ON SQ-16 NOZZLE AT 40 M. P. H.

| Angle of pitch or yaw (degrees) | Differential head ¹ (inches of water) | | Angle of pitch or yaw (degrees) | Differential head ¹ (inches of water) | |
|---------------------------------|--|--------------|---------------------------------|--|--------------|
| | Nozzle pitched | Nozzle yawed | | Nozzle pitched | Nozzle yawed |
| 0 | +0.757 | +0.757 | 0 | +0.757 | +0.757 |
| -5 | .758 | .767 | 5 | .766 | .767 |
| -10 | .758 | .787 | 10 | .788 | .789 |
| -15 | .778 | .808 | 15 | .817 | .815 |
| -20 | .794 | .822 | 20 | .836 | .838 |
| -30 | .771 | .816 | 30 | .817 | .857 |
| -40 | .721 | .706 | 40 | .751 | .784 |
| -50 | .623 | .615 | 50 | .615 | .748 |
| -60 | .440 | .447 | 60 | + .428 | .595 |
| -70 | + .104 | + .011 | 70 | - .042 | + .157 |
| -80 | - .236 | - .367 | 80 | - .345 | - .253 |
| -90 | - .356 | - .646 | 90 | - .545 | - .544 |
| -100 | | | 100 | | - .383 |
| -110 | + .046 | - .250 | 110 | - .200 | - .106 |
| -120 | | | 120 | | + .038 |
| -130 | + .060 | + .015 | 130 | - .083 | + .049 |
| -140 | | | 140 | | + .045 |
| -150 | - .068 | - .005 | 150 | - .078 | - .038 |
| -160 | | | 160 | | - .125 |
| -170 | - .076 | - .133 | 170 | - .071 | - .129 |
| -180 | - .073 | - .091 | 180 | - .073 | - .092 |

¹ Tabulated differential head is mean of five readings.

TABLE III
 VELOCITY CORRECTION FACTOR¹

| Angle of pitch or yaw (degrees) | SQ-16 nozzle | | Zahm nozzle | | Angle of pitch or yaw (degrees) | SQ-16 nozzle | | Zahm nozzle | |
|---------------------------------|--------------|--------|-------------|--------|---------------------------------|--------------|--------|-------------|--------|
| | In pitch | In yaw | In pitch | In yaw | | In pitch | In yaw | In pitch | In yaw |
| 0 | +1.000 | +1.000 | +1.000 | +1.000 | 0 | +1.000 | +1.000 | +1.000 | +1.000 |
| -5 | 1.001 | 1.007 | | | 5 | 1.006 | 1.007 | | |
| -10 | 1.001 | 1.020 | 1.013 | 1.015 | 10 | 1.021 | 1.021 | 1.013 | 1.022 |
| -15 | 1.014 | 1.033 | | | 15 | 1.039 | 1.038 | | |
| -20 | 1.024 | 1.043 | 1.009 | .979 | 20 | 1.051 | 1.052 | 1.024 | 1.020 |
| -30 | 1.009 | 1.038 | .980 | .942 | 30 | 1.039 | 1.064 | 1.013 | .991 |
| -40 | .976 | .965 | .934 | .897 | 40 | .978 | 1.017 | .976 | .963 |
| -50 | .907 | .894 | .849 | .824 | 50 | .901 | .994 | .914 | .909 |
| -60 | .762 | .769 | .741 | .739 | 60 | +.492 | .886 | .838 | .835 |
| -70 | +.371 | +.121 | .590 | .618 | 70 | -.236 | +.455 | .717 | .742 |
| -80 | .559 | -.697 | .406 | .456 | 80 | -.675 | -.578 | .594 | .599 |
| -90 | -.686 | -.924 | +.187 | +.316 | 90 | -.848 | -.848 | +.375 | +.424 |
| -100 | | | -.100 | -.103 | 100 | | -.711 | -.200 | -.215 |
| -110 | +.247 | -.575 | -.000 | -.049 | 110 | -.514 | -.375 | -.229 | -.201 |
| -120 | | | +.106 | +.124 | 120 | | -.224 | -.193 | -.069 |
| -130 | +.282 | +.141 | -.061 | .124 | 130 | -.331 | -.254 | -.141 | +.077 |
| -140 | | | -.154 | .103 | 140 | | -.244 | -.141 | +.069 |
| -150 | -.300 | -.257 | -.094 | .098 | 150 | -.321 | -.224 | -.162 | -.049 |
| -160 | | | +.035 | .034 | 160 | | -.407 | -.122 | -.034 |
| -170 | -.317 | -.420 | .079 | .098 | 170 | -.307 | -.413 | -.061 | -.060 |
| -180 | -.310 | -.347 | +.061 | +.034 | 180 | -.310 | -.348 | +.050 | .000 |

¹ Data of Tables I and II used in computing these factors.

TABLE IV
 INVERSE VELOCITY CORRECTION FACTOR¹

| Angle of pitch or yaw (degrees) | SQ-16 nozzle | | Zahm nozzle | | Angle of pitch or yaw (degrees) | SQ-16 nozzle | | Zahm nozzle | |
|---------------------------------|--------------|---------|-------------|----------|---------------------------------|--------------|---------|-------------|----------|
| | In pitch | In yaw | In pitch | In yaw | | In pitch | In yaw | In pitch | In yaw |
| 0 | +1.000 | +1.000 | +1.000 | +1.000 | 0 | +1.000 | +1.000 | +1.000 | +1.000 |
| -5 | .999 | .993 | | | 5 | .994 | .993 | | |
| -10 | .999 | .980 | .987 | .985 | 10 | .979 | .979 | .987 | .978 |
| -15 | .986 | .968 | | | 15 | .962 | .963 | | |
| -20 | .977 | .959 | .991 | 1.021 | 20 | .951 | .951 | .977 | .980 |
| -30 | .991 | .963 | 1.020 | 1.062 | 30 | .962 | .940 | .987 | 1.009 |
| -40 | 1.025 | 1.036 | 1.071 | 1.114 | 40 | 1.022 | .983 | 1.025 | 1.038 |
| -50 | 1.103 | 1.119 | 1.178 | 1.214 | 50 | 1.110 | 1.006 | 1.094 | 1.100 |
| -60 | 1.312 | 1.300 | 1.350 | 1.353 | 60 | +.2.033 | 1.129 | 1.193 | 1.198 |
| -70 | +.2.695 | +.8.264 | 1.695 | 1.618 | 70 | -.4.237 | +.2.198 | 1.395 | 1.348 |
| -80 | -1.789 | -1.435 | 2.463 | 2.193 | 80 | -1.481 | -1.730 | 1.634 | 1.669 |
| -90 | -1.458 | -1.082 | +.5.348 | +.3.165 | 90 | -1.179 | -1.179 | +.2.667 | +.2.358 |
| -100 | | | -10.000 | -9.709 | 100 | | -1.406 | -5.000 | -4.651 |
| -110 | +.4.049 | -1.739 | ∞ | -20.408 | 110 | -1.946 | -2.667 | -4.367 | -4.975 |
| -120 | | | +.9.434 | +.8.065 | 120 | | -4.464 | -5.181 | -14.493 |
| -130 | +.3.546 | +.7.092 | -16.393 | 8.065 | 130 | -3.021 | -3.937 | -7.092 | +.12.987 |
| -140 | | | -6.494 | 9.709 | 140 | | -4.098 | -7.092 | +.14.493 |
| -150 | -3.333 | -3.891 | -10.638 | 10.204 | 150 | -3.115 | -4.464 | -6.173 | -20.408 |
| -160 | | | +.28.571 | 29.411 | 160 | | -2.457 | -8.197 | -29.412 |
| -170 | -3.155 | -2.381 | 12.658 | 10.204 | 170 | -3.257 | -2.421 | -16.393 | -16.667 |
| -180 | -3.226 | -2.882 | +.16.393 | +.29.412 | 180 | -3.226 | -2.874 | +.20.000 | ∞ |

¹ Reciprocal of value in Table III.