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CCD photometry in the Vilnius system in the vicinity of the globular cluster M 56

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Abstract. CCD observations of field stars in an area north-east of the globular cluster M 56 were obtained in six bands of the Vilnius photometric system. The data sets cover a field of $9' \times 9'.5$. An outline of the data pathway from observations to reduction via IRAF is outlined in this text. Photometry of 366 stars brighter than 18th V magnitude has been obtained and the analysis of the observational errors is discussed.

Key words. stars: fundamental parameters – stars: general – galaxy: globular clusters: individual: M 56

1. Introduction

This paper is in continuation of a series of papers reporting CCD photometry in the Vilnius photometric system (hereafter VS). The VS, that consists of seven intermediate band-passes (*U(345,40), P(374,26), X(405,22), Y(466,26), Z(516,21), V(544,26), S(656,20)*, where numbers indicate the central wavelength and half-width in nanometer respectively) makes possible purely photometric determination of spectral classes, absolute magnitudes and metallicities of stars in presence of significant interstellar reddening and without any preselection of objects (Straižys 1992). Consequently, any collection of stars including samples of different temperatures, luminosities, populations, interstellar reddenings, and peculiarities can be classified. The VS and the recently defined Strömvil system (Straižys et al. 1996; Boyle et al. 2000) are the only ones able to solve such a wide variety of classification problems. Such data are important for questions relating to the structure and evolution of our Galaxy. In fact the present models of the spatial distribution of stars in the Galaxy are based on star counts in the photographic version of the UBV and RGU systems with only a crude estimate of stellar types. Moreover, in calculations of models of the Galaxy, a number of assumptions considering the luminosity and metallicity functions have been adopted (Bahcall 1986; Bahcall & Soneira 1980, 1981, 1984; Gilmore 1989).

An attempt to realize photographically the VS has been made by Smriglio et al. (1986) at the 60/90/183 cm Schmidt telescope of Rome Astronomical Observatory at Campo Imperatore (Italy) and at the Vatican Observatory 63/98/240 cm Schmidt telescope. An area of two square degrees in the direction of the globular cluster M 56, but excluding the cluster, has been investigated and a catalogue of seven-band photometry of 752 stars is available at the Strasbourg Data Center (Smriglio et al. 1987). Unfortunately, the errors for stars fainter than $V = 11$–12 mag were too large for a reliable classification. Then the relatively low accuracy of the photographic technique and also the large scale of the Schmidt telescope dissuaded us from further use of this observational technique.

Especially wide possibilities are opened for investigation of star fields when the VS is realized with CCD detectors. Then, after this photographic attempt, two more regions were observed in the seven band-passes of the VS, again in the vicinity of M 56, but using CCD photometry (Boyle et al. 1990, hereafter Paper I). The CCD frames have been obtained with the 0.9-meter telescope at Kitt Peak National Observatory. The accuracy attained in this second case was 0.04 mag, and was still not high enough to achieve reliable estimates of absolute magnitude and metallicity. However, even this accuracy allowed us to obtain MK predictions for G-K-M stars down to 17th V magnitude (Smriglio et al. 1990) and interstellar extinction (Smriglio et al. 1991). Until now stars this faint were inaccessible for two-dimensional classification. Moreover, following a statistical approach developed by Münch (Münch 1952; Knude 1979), the cloudy structure of interstellar dust and the gas-to-dust ratio in the observed direction have been studied (Smriglio et al. 1995).

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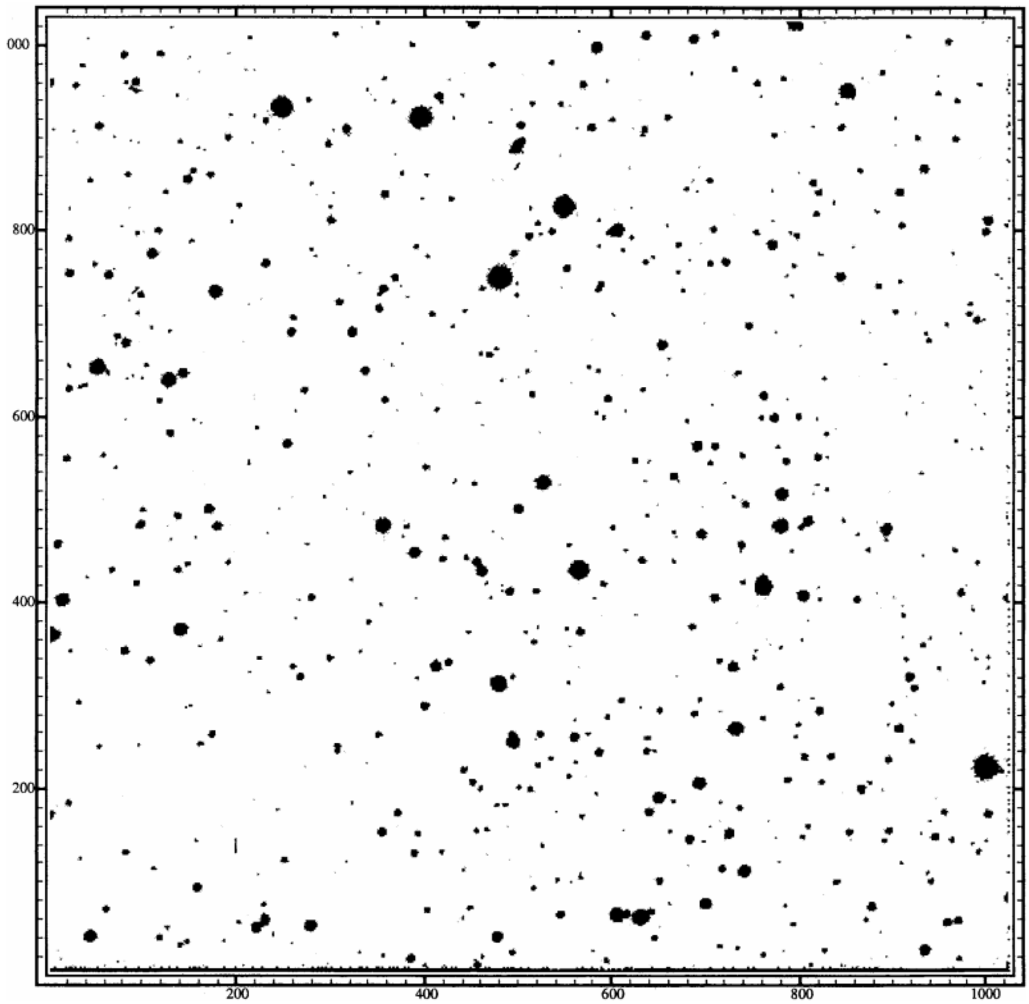

Fig. 1. The finding chart of the studied field. North is up, east is to the left. The central pixel (Xc: 512; Yc: 512) is at RA $19^{h}14^{m}53\overset{s}{.}7$, Dec $+30°14'22''$ (1950.0). The X, Y pixel coordinates, with respective origin at the East and South, correspond to those in Table 5 (see Appendix).

We think that this sort of photometry in selected galactic regions will enable us to determine more accurate stellar distribution functions and then to calculate a more realistic Galaxy model. As this will be possible only when high-quality observational material becomes available, this purpose must be considered as the long-term strategy of the project.

At the present moment the main aim of this photometry is to achieve a satisfactory accuracy for producing reliable two/three-dimensional classifications for stars as faint as possible. In particular in this paper we intend to test which observational possibilities can be attained by using CCD photometry in VS with 1.5-meter class telescopes. For this reason we selected a region NE of M 56, with the following prerogatives: (a) the area must be two-three times larger than the previous one (Paper I) and (b) it must include, for photometric calibration, this already-studied area with at least the same standard stars established photoelectrically in this field by Janulis (1986, Paper II). This particular area has been selected mainly for the availability of a suitable number of both photoelectric and CCD standards. The mixture of disk and old population objects, due to the proximity of the globular cluster M 56, is not a problem, because a purely photometric classification by using automated methods permits a satisfactory separation either of normal or metal-deficient stars. Moreover we also have the opportunity of measuring the metallicity of this poorly-known globular cluster, that will be an object of a future paper. Furthemore, keeping in mind the long-term strategy, this region is suitable to test the capability of the VS to work in a dust-reddened region in the neighbourhood of the galactic plane ($b \sim 10°$).

2. Observations

The observations using six Vilnius filters (P, X, Y, Z, V, S) were made on three nights in July 1995, October 1995 and July 1996 with the 1.52 m telescope of the Osservatorio Astronomico di Bologna at Loiano (Italy).

The U filter of the Vilnius system was not used due to the very low UV efficiency of the CCD camera. Any

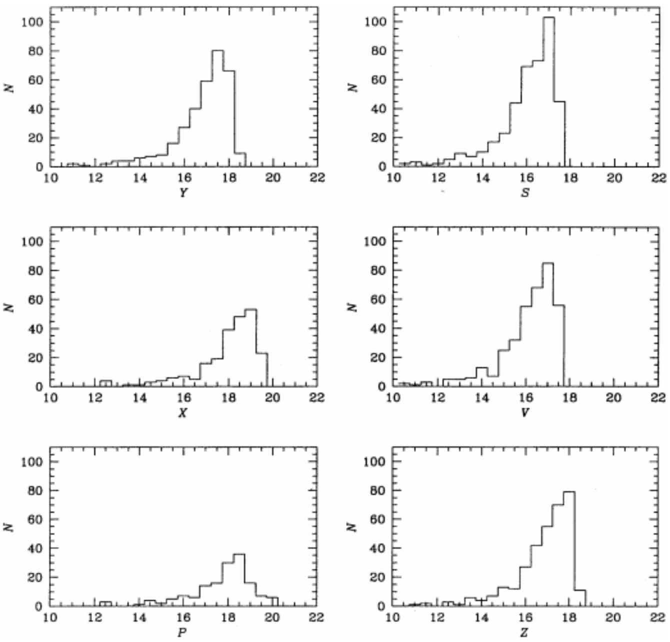

Fig. 2. Observed magnitude distribution in each band for all the stars listed in the catalogue (see Table 5 in Appendix): the stars are binned by 0.5 mag and the distributions are not smoothed.

leaks outside the desired band were less than 1% transmission across a spectral region from 0.3 to 1.2 micron. A cryogenically-cooled CCD camera consisting of a Thomson TH 7896A CDA chip with 1024 × 1024 pixels, each 19 μ square, operated at −130 °C was used. The chip size corresponds to 9.6 × 9.6 arcmin at the f/8 Cassegrain focus of the telescope.

The center of the new field is at RA = $19^{\rm h}14^{\rm m}53\overset{\rm s}{.}7$ and Dec = $+30°14'22''$ (1950.0) and is about 9 arcmin NE of the globular cluster center. We think that it falls radially far enough away from M 56 to be probably populated by a mixture of cluster members and also field stars. It contains 10 photoelectric standards, (see Table 1) established by Janulis (Paper II) including, as mentioned above, the 6 standards which have been used for calibration by Boyle et al. in Paper I.

The exposure times were the following: 20 min in P, 15 min in X, 10 min in Y and 5 min in the rest of the filters. Two (P) or three exposures have been made in each filter during each period of observation and a selection has been done according to the quality of the seeing.

It is worth noting that this procedure neither demands a prior knowledge of the CCD sensitivity nor the filter transmissions. This method is independent of any system and/or CCD.

3. Reductions

The data were reduced at Istituto Astronomico, Universita' di Roma "La Sapienza" (from this time on merged with the Physics Department in the same University) by A. K. Dasgupta using the crowded field photometry package DAOPHOT from IRAF in the point-spread function (psf) mode (Tody 1986, 1993; Stetson 1987). The flatfielding was done using 3 dome-flat exposures in each band-pass. Flatfielded exposures in each filter were aligned by the task imalign and then added in order to improve the signal-to-noise ratio (Newberry 1994). In the imcombine task we set "combine" = average, and "reject" = crreject. In this rejection set-up, low pixels are ignored and only high pixels are rejected. This is to ensure that any star falling on a bad pixel or trap is rejected. This will also remove any star affected by cosmic rays. We have performed photometry on the combined image from each filter using tasks: phot, psf, nstar, substar and allstar in this order. The psf stars were selected using pstselect procedure.

The task psf was run interactively using the output list from pstselect and then accepting or rejecting a candidate for a psf star after inspecting the profile and the contour of the star. A good candidate psf star must have no neighbours within *fitrad* pixels and also must be free of cosmetic blemishes. The *fitrad* ≈ *fwhm* was set for each combined image per filter. The *fwhm* and *sky* σ were obtained from each combined image per filter, respectively using the task imexamine. These procedures were repeated until we had a good list of psf stars that do not contain any non-stellar, multiple, or cosmetic blemishes. Following this procedure the instrumental magnitudes were obtained for all the band-passes respectively.

The instrumental magnitudes ($m_{\rm ccd}$) for each filter were converted to the standard ones ($m_{\rm st}$) of the VS using color-magnitude (CM) equation of the form:

$$m_{\rm ccd} = m_{\rm st} + m_0 + m_1(Y-V)_{\rm st} \quad (1)$$

where the $(Y-V)$ is the color index most sensitive to temperature. The coefficient m_0 is the zero point shift and m_1 is the first order color coefficient (slope). The values of the coefficient were obtained using task fitparams as described

Table 1. The list of Vilnius photoelectric standard stars observed in the studied area taken from Paper II (stars used in Paper I are marked by "*"; the numbers in the second column are the same of the first column in Table 5).

N.	CCD N.	V	$U-P$	$P-X$	$X-Y$	$Y-Z$	$Z-V$	$V-S$
53	364	10.66	0.47	0.67	0.86	0.37	0.21	0.56
56	310	12.79	0.45	0.68	0.78	0.34	0.23	0.54
58*	294	14.34	0.37	0.61	0.81	0.37	0.25	0.53
59*	273	12.52	1.02	1.44	1.83	0.59	0.48	0.99
60*	259	13.37	0.54	0.74	0.95	0.40	0.29	0.65
63*	244	14.23	0.34	0.70	0.85	0.36	0.21	0.66
64*	241	13.75	0.57	0.64	0.96	0.38	0.29	0.65
66	181	11.94	0.74	1.25	1.87	0.58	0.52	1.04
70	115	11.66	0.68	1.11	1.52	0.57	0.41	0.92
71	75	11.23	0.63	0.85	0.50	0.22	0.10	0.29

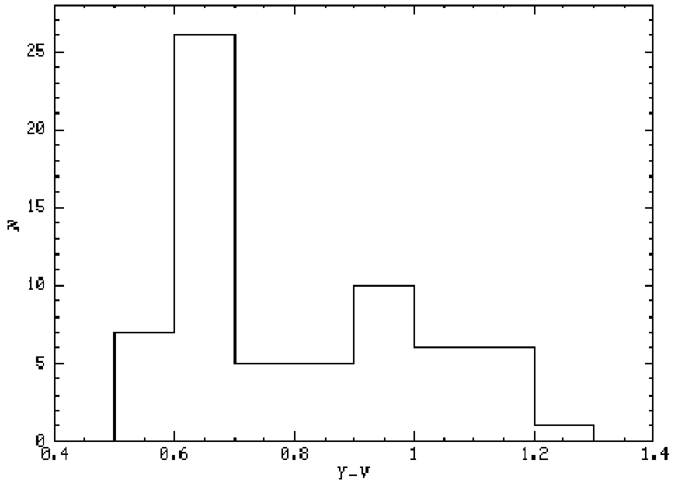

Fig. 3. Distribution of stars brighter than $V = 15.5$ mag per interval of 0.1 mag of the $Y-V$ color index.

Table 2. The zero-point m_o, the slope of CM equations m_1 with their errors and dispersion of CM equations for all band-passes.

Filters	P	X	Y	Z	V	S
m_0	8.163	7.130	7.006	6.932	6.919	7.732
errors	0.025	0.009	0.016	0.030	0.027	0.021
m_1	−0.032	−0.021	−0.007	0.009	0.045	−0.004
errors	0.034	0.012	0.021	0.039	0.035	0.028
dispersion	0.020	0.008	0.014	0.026	0.023	0.018

in IRAF help pages. The output from *fitparams* for zero-point (m_0) and slope (m_1) with their errors and dispersion of the CM equations for each filter are given in Table 2.

4. Results

The final catalogue is presented in Table 5 (see Appendix), where ten columns consecutively give (1) the sequential running number, (2) and (3) respectively the coordinates Xc and Yc in pixels of the center of each star image, (4) the CCD V magnitude in the VS and (5) to (10) the Vilnius color indices $Y-V$, $P-X$, $X-Y$, $Y-Z$, $Z-V$ and $V-S$.

The list of the 366 stars is complete in V magnitude from $V = 10.64$ (the brightest value in the field) to $V \leq 18$ mag and 45 stars, whose V magnitudes were not available, have been omitted. Moreover, following a criterion already used in preceding papers of the same series, the stars are ordered by increasing the coordinate Xc in pixel and can be easily identified in Fig. 1.

In Table 3 are listed the percentages of each Vilnius color index measured in this area. It clearly shows the decreasing number of each measured color index moving from the redward to the blueward side of the spectrum.

The histograms in Fig. 2 show the apparent luminosity function in each band per interval of half a magnitude. The peaks of the distributions are between 17 and 18 mag-intervals for Y, Z, V, S bands and fainter than 18 for P and X. Moreover the numbers of observed magnitudes in each band are decreasing from redward band-passes to the blueward ones. This occurrence, as well as that appearing in Table 3, is due to the low UV efficiency of the CCD chip.

In Fig. 3 we plotted the apparent luminosity function of stars, brighter than $V = 15.5$ mag, per 0.10 mag interval of the color index $Y-V$.

Table 3. Percentage of measurements available in each color index for the 366 stars listed in the Catalogue.

color index	$Y-V$	$P-X$	$X-Y$	$Y-Z$	$Z-V$	$V-S$
percentage	≃86%	≃40%	≃62%	≃82%	≃87%	≃99%

We suspect that the peak corresponding to the red giant stars must be a mixture of field stars and cluster members, due to the proximity of the globular cluster. A rough test, subdividing the whole area (Fig. 1) in four quadrants and identifying the red giants appearing in each one, seems to support this argument. In fact in the SW quadrant, which is the nearest to the cluster, we can observe about 45% of the objects, whilst the remaining 55% is distributed in the area three times larger represented by the NW, NE and SE quadrants. On the other hand Rosino (1944) has estimated a diameter of 14 to 15 arcmin for M 56 and the center of the SW quadrant is about 7 arcmin away from the cluster center.

Measurements of metallicity for selecting the metal deficient population by using this photometry will be an object of a later paper.

The photon statistics errors $V_{\rm err} = 1/(\text{signal/noise})$, as calculated by DAOPHOT for V magnitudes, are plotted in Fig. 4 as a function of magnitude. From this graph one can see that up to $V \simeq 14$ mag $V_{\rm err}$ is of the order of 0.5%, for magnitude ≃15.5 the error is about 1% and it increases to 3% up to ≃17 mag. Moreover, it is important to note that down to this magnitude the dispersion of points remains within 0.005 mag and this makes useless any polynomial fit for estimating the "typical error" with magnitude. This result is confirmed for all the band-passes of the VS used in this photometry.

The photometric errors were derived by fitting first order *spline* function with CCD magnitudes of all the 10 standard stars available in the area against their corresponding photoelectric magnitudes. The rms errors are listed in Table 4.

From Table 4 it appears that the photometric errors of the present photometry remain between 1% and 2% in all the band-passes. By the propagation of errors we obtain an rms error ≤2% for all the color indices, except the indices including the P magnitude.

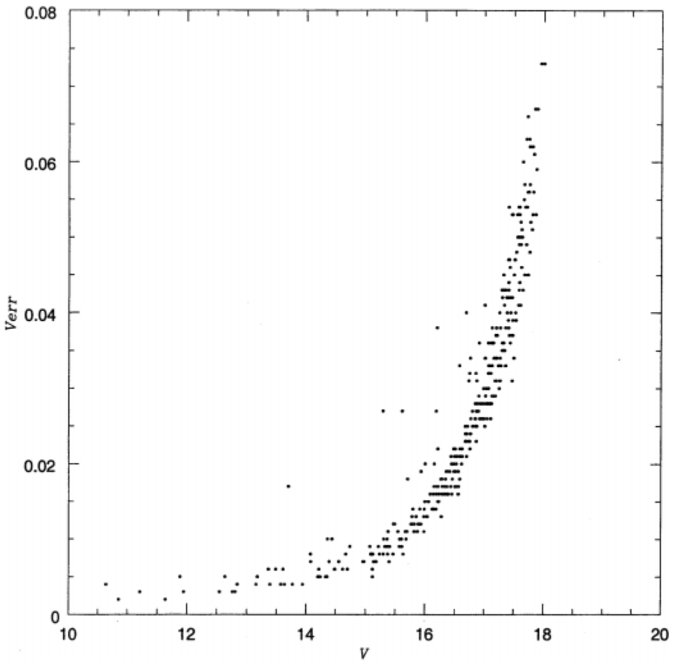

Fig. 4. The photometric errors V_{err} from DAOPHOT for all the stars of the catalogue plotted against V magnitude.

Table 4. The rms errors of the present photometry and of Paper I photometry for each Vilnius band-pass.

band-passes	*P*	*X*	*Y*	*Z*	*V*	*S*
rms error this paper	0.022	0.007	0.019	0.019	0.016	0.013
rms error Paper I	0.030	0.025	0.025	0.027	0.013	0.014

In such a case the error does not exceed 3%. Bearing in mind that in Paper II Janulis quotes the rms errors for the photoelectric standards as $\pm 0.01^{m}$ for V and redward color indices and $\pm 0.02^{m}$ for the blueward color indices, we can say that we are approaching the accuracy of these standards, except for the P-band.

A direct comparison between our previous CCD photometry (Paper I) and this one can be obtained by using the 5 Janulis standards which are common to both photometries. We have again used a *spline* function of first order to obtain the rms values relative to Paper I, which are also shown in Table 4. The corresponding errors for the present photometry using only these 5 stars are not listed in Table 4 because they do not differ significantly from those calculated by using all the ten available standards. From these data it appears that in Paper I the rms error of color indices ranges between $\pm 0.03^{m}$ and $\pm 0.04^{m}$, the upper limit being assumed again when ultraviolet magnitudes are involved. We think that this improvement can be attributed mainly to the accuracy of the psf photometry with respect to the aperture photometry performed in Paper I. Also the larger size of Loiano 1.52-meter telescope, compared to that of the 0.9-meter telescope used in KPNO, contributes to this result. On the other hand the CCD chip used at the focus of the smaller telescope was good enough to allow us to measure the U magnitudes presented in Paper I.

5. Conclusions

Multicolor stellar photometry in the band-passes $PXYZVS$ of the Vilnius system has been carried out in an area of about 90 arcmin^2. The data reductions have been made by using the crowded field photometry package DAOPHOT from IRAF in the point-spread function and a catalogue of 366 stars with V magnitudes down to 18 is presented in this paper. Only 40% of the listed stars present the P magnitude, due to the low ultraviolet efficiency of the CCD chip available at Loiano at the time of our observing run. The other magnitudes are available in 82–99% of the cases. This situation can be easily improved by using a chip more efficient in the ultraviolet, which will be available in the near future. But in spite of this present condition, the most important result is that the rms error of the photometry ranges between 1% and 2% for all the color indices, except when the P magnitude is involved, in which case it is $\leq$3%. The previous photometry carried out in the same field with a smaller telescope by the same authors produced a better completeness because of a more efficient chip in the ultraviolet, but a larger error ranging from 3% to 4%.

In conclusion, by using a 1.5-meter class telescope, the accuracy of the aperture photometry previously carried out with a 0.9-meter telescope has been clearly improved. This accuracy can get better by using 2-meter class telescopes and, above all, a CCD chip with high ultraviolet efficiency. Moreover, a further effort must be made to establish standards with accuracy better than 1% down to fainter magnitudes. Once the practical instrumental improvements are realized, these CCD observations permit us in general to study the stellar distribution in low galactic latitude up to V = 16–17 mag for a wide variety of stars.

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Appendix A:

Table 5. CCD photometry in the Vilnius system.

N	*Xc*	*Yc*	*V*	*Y−V*	*P−X*	*X−Y*	*Y−Z*	*Z−V*	*V−S*
1	10.1	462.2	16.00	....	....	....	....	0.39	0.86
2	15.3	402.1	13.49	0.64	0.44	1.02	0.43	0.22	0.61
3	19.9	553.9	16.59	0.84	....	1.52	0.48	0.37	0.74
4	21.9	629.5	16.63	1.03	....	....	0.69	0.34	0.86
5	22.0	182.7	16.97	0.67	0.69	0.86	0.51	0.16	0.68
6	22.8	790.5	16.59	0.88	....	1.53	0.51	0.36	0.79
7	23.0	753.5	15.94	0.86	0.47	1.58	0.50	0.36	0.81
8	29.9	955.4	16.87	0.78	....	1.24	0.43	0.35	0.70
9	32.4	291.0	17.24	0.92	....	....	0.55	0.38	0.79
10	33.5	630.3	17.64	....	....	....	....	0.20	0.69
11	36.5	977.2	17.13	0.70	....	0.95	0.43	0.26	0.56
12	39.9	633.3	17.56	0.74	....	....	0.42	0.32	0.77
13	44.9	39.7	14.44	1.18	....	1.91	0.71	0.47	1.05
14	45.1	853.5	17.33	....	....	....	....	0.45	0.87
15	49.7	763.0	17.20	0.78	....	....	0.47	0.31	0.60
16	52.9	652.7	12.84	0.61	0.37	1.01	0.39	0.22	0.58
17	54.6	911.9	15.99	0.85	....	1.36	0.51	0.34	0.82
18	62.3	68.8	16.51	0.67	....	1.04	0.44	0.22	0.69
19	64.7	646.5	17.38	0.61	....	0.99	0.33	0.28	0.74
20	65.4	751.6	15.82	0.96	....	1.53	0.59	0.37	0.85
21	68.5	435.2	16.77	0.76	....	0.99	0.46	0.30	0.59
22	74.4	685.8	16.77	0.81	....	1.13	0.55	0.25	0.70
23	81.5	988.2	16.45	0.79	....	1.08	0.52	0.26	0.61
24	82.1	347.0	15.85	0.73	0.38	1.02	0.48	0.24	0.67
25	83.2	130.0	16.85	0.74	0.16	0.84	0.50	0.24	0.60
26	83.6	678.4	15.33	0.64	0.34	1.02	0.41	0.22	0.61
27	85.6	859.7	17.07	0.79	....	....	0.59	0.20	0.67
28	94.1	959.4	16.20	0.91	....	....	0.49	0.42	0.82
29	94.4	949.7	17.48	....	....	....	....	....	0.68
30	95.1	420.1	16.63	0.71	0.18	1.07	0.43	0.28	0.63
31	95.8	796.9	17.30	0.72	....	1.06	0.41	0.31	0.56
32	96.7	710.3	17.67	0.73	....	....	....	....	0.73
33	99.3	730.6	16.99	1.12	....	....	0.44	0.68	1.12
34	100.4	483.9	16.19	0.77	....	1.10	0.51	0.26	0.67
35	101.8	499.2	17.41	....	....	....	....	....	0.86
36	105.3	654.8	17.57	0.79	....	....	0.44	0.35	0.63
37	109.0	336.7	16.24	0.91	....	1.41	0.53	0.37	0.82
38	111.8	774.9	14.96	0.70	0.38	1.05	0.46	0.24	0.62
39	112.4	113.1	17.60	....	....	....	....	....	0.69
40	117.5	799.8	16.85	1.07	....	....	0.71	0.36	0.95
41	118.9	616.0	17.12	0.91	....	1.22	0.58	0.33	0.71
42	118.9	38.2	16.59	0.75	0.53	1.02	0.58	0.17	0.68
43	120.3	989.6	16.86	0.82	....	1.17	0.44	0.38	0.70
44	128.6	638.7	13.57	0.85	0.84	1.72	0.37	0.48	0.84
45	129.8	581.7	16.30	1.11	....	....	0.65	0.45	0.92
46	137.4	944.5	17.73	....	....	....	....	0.19	0.65
47	138.2	492.3	16.34	0.67	....	0.94	0.43	0.24	0.56
48	138.3	434.4	16.42	0.77	....	1.18	0.48	0.29	0.81
49	140.3	30.1	17.22	....	....	....	....	0.51	0.88
50	141.2	370.1	13.61	0.65	0.43	1.08	0.41	0.23	0.63
51	143.8	646.0	15.14	0.66	0.37	1.09	0.42	0.24	0.65
52	147.9	34.0	17.41	....	....	....	....	0.29	0.67

Table 5. continued.

N	*Xc*	*Yc*	*V*	*Y−V*	*P−X*	*X−Y*	*Y−Z*	*Z−V*	*V−S*
53	148.2	854.8	15.70	0.98	....	1.84	0.53	0.45	0.91
54	148.4	440.8	17.13	0.89	....	....	0.53	0.36	0.68
55	154.8	863.5	17.20	0.73	....	....	0.39	0.33	0.74
56	158.9	92.0	15.47	0.57	0.71	0.88	0.37	0.20	0.64
57	162.2	246.4	17.32	....	....	....	....	0.62	0.76
58	171.5	499.7	15.08	0.78	0.86	0.94	0.49	0.29	0.69
59	172.9	859.7	16.32	0.74	....	1.23	0.44	0.30	0.72
60	174.6	257.2	16.36	0.74	0.82	1.00	0.47	0.27	0.71
61	178.1	733.7	13.94	1.06	0.84	1.77	0.64	0.42	0.93
62	179.7	481.3	15.39	0.96	1.02	1.27	0.52	0.44	0.85
63	191.0	899.9	16.56	1.03	....	....	0.62	0.41	0.83
64	191.1	442.6	17.27	0.89	....	....	0.49	0.41	0.64
65	193.7	924.0	17.94	....	....	....	....	....	0.86
66	202.8	54.2	17.74	....	....	....	....	....	0.79
67	202.8	826.5	17.26	0.81	....	....	0.36	0.45	0.91
68	212.7	549.7	17.56	....	....	....	....	0.38	0.61
69	221.3	49.4	14.37	0.62	0.66	0.74	0.44	0.18	0.59
70	223.8	338.6	17.36	0.74	0.01	0.96	0.52	0.22	0.66
71	228.9	73.9	17.43	0.81	0.54	1.06	0.53	0.28	0.67
72	230.5	58.3	15.62	0.76	0.86	0.99	0.44	0.31	0.72
73	230.8	917.2	16.87	0.84	....	....	0.35	0.49	0.84
74	231.2	764.5	16.05	0.81	....	1.58	0.37	0.44	0.77
75	248.6	932.0	11.22	0.37	0.82	0.49	0.24	0.13	0.30
76	250.3	121.7	16.68	0.90	1.08	1.17	0.56	0.34	0.85
77	253.9	570.3	15.30	0.69	0.34	1.00	0.43	0.26	0.64
78	258.3	690.1	15.77	0.76	0.44	1.20	0.45	0.31	0.74
79	260.0	330.0	17.19	0.70	....	1.15	0.33	0.37	0.66
80	260.7	705.7	17.34	0.86	....	....	0.38	0.47	0.89
81	267.6	319.3	16.19	0.51	0.94	0.94	0.38	0.13	0.75
82	272.5	627.8	16.85	1.06	....	....	0.55	0.51	0.91
83	276.2	940.0	17.08	0.73	....	1.13	0.40	0.32	0.68
84	279.1	51.0	14.07	0.59	0.66	0.70	0.41	0.18	0.60
85	297.3	892.5	16.76	0.81	0.26	1.01	0.52	0.29	0.59
86	299.0	339.2	16.70	0.95	....	....	0.51	0.44	0.85
87	300.7	810.4	15.99	0.72	0.21	1.13	0.44	0.28	0.68
88	305.1	1010.4	17.47	0.76	....	....	....	....	0.64
89	307.5	244.5	16.74	0.82	....	1.22	0.46	0.35	0.72
90	309.4	722.4	16.50	0.79	....	1.45	0.37	0.42	0.74
91	316.8	909.3	15.78	0.85	....	1.32	0.48	0.37	0.78
92	320.9	539.5	17.58	....	....	....	....	0.41	0.72
93	322.5	182.5	15.48	0.35	....	....	....	....	....
94	323.5	690.5	15.12	0.73	0.35	1.20	0.44	0.30	0.71
95	337.1	648.5	15.89	0.83	....	1.55	0.36	0.47	0.84
96	350.7	256.6	17.04	0.76	....	1.20	0.41	0.34	0.68
97	351.8	715.8	16.75	0.91	....	....	0.49	0.42	0.77
98	355.0	151.8	15.50	0.68	0.68	0.83	0.44	0.23	0.62
99	355.1	19.0	16.91	1.16	....	0.86	0.45	0.70	0.17
100	356.1	482.5	13.37	1.02	1.39	1.55	0.57	0.45	0.95
101	356.4	737.1	15.82	0.75	0.41	1.27	0.44	0.31	0.70
102	357.1	963.7	17.61	....	....	....	....	....	0.84
103	357.9	617.5	16.37	0.61	0.22	1.01	0.37	0.24	0.64
104	357.9	838.7	15.80	0.83	0.56	1.58	0.42	0.41	0.80

Table 5. continued.

N	Xc	Yc	V	$Y-V$	$P-X$	$X-Y$	$Y-Z$	$Z-V$	$V-S$
105	366.8	938.3	17.83	....	....	....	....	....	0.83
106	368.5	749.0	16.15	0.69	0.35	1.01	0.40	0.29	0.60
107	371.5	172.5	16.52	0.70	0.92	1.09	0.40	0.30	0.74
108	381.0	480.7	17.34	0.71	....	....	0.44	0.27	0.67
109	385.1	15.8	15.71	0.96	0.61	1.05	0.46	0.50	0.42
110	386.6	999.3	17.01	0.65	....	1.10	0.42	0.23	0.60
111	389.3	129.0	16.49	0.74	0.70	0.96	0.45	0.29	0.63
112	390.0	453.3	14.56	0.61	0.64	0.70	0.38	0.23	0.57
113	391.6	782.6	17.30	0.66	....	....	0.33	0.34	0.62
114	393.5	150.5	16.81	1.16	....	....	0.67	0.49	0.84
115	396.0	921.4	11.64	1.00	1.09	1.52	0.61	0.39	0.92
116	400.5	287.8	16.04	0.96	....	1.49	0.55	0.42	0.88
117	401.8	544.8	16.84	0.83	....	1.07	0.51	0.31	0.63
118	402.6	859.4	17.82	....	....	....	....	....	0.67
119	403.0	68.4	16.68	....	....	....	....	0.27	0.59
120	403.9	772.0	17.58	0.67	....	....	....	....	0.60
121	408.6	709.7	17.07	0.88	....	....	0.51	0.36	0.81
122	412.4	330.3	14.74	0.73	0.72	0.89	0.44	0.29	0.68
123	413.1	607.2	17.76	....	....	....	....	....	0.81
124	415.8	944.4	16.09	0.69	0.29	1.04	0.44	0.25	0.60
125	418.4	130.7	17.30	0.85	0.77	0.95	0.62	0.23	0.70
126	419.6	446.2	16.62	0.99	0.76	1.07	0.34	0.65	0.73
127	422.0	469.4	17.11	0.94	0.92	0.79	0.47	0.47	0.80
128	425.8	334.8	16.44	1.09	....	....	0.58	0.51	0.87
129	428.4	833.6	17.40	0.67	....	....	....	....	0.74
130	429.4	696.2	16.50	....	....	....	....	....	....
131	440.2	945.4	13.45	....	....	....	....	....	....
132	441.9	218.8	17.02	0.77	....	....	0.37	0.40	0.83
133	447.2	367.8	17.59	...		....	....	....	....
134	448.0	70.6	16.99	0.79	....	0.99	0.57	0.21	0.83
135	451.2	205.5	16.37	0.69	0.66	0.95	0.44	0.25	0.72
136	451.5	1023.8	14.40	1.13	....	1.82	....	....	0.84
137	453.2	527.1	17.44	0.74	....	....	....	....	0.66
138	455.6	443.8	15.55	0.69	0.67	0.86	0.43	0.26	0.65
139	459.9	199.2	17.09	1.02	....	....	0.51	0.51	0.73
140	461.2	433.7	14.49	0.64	0.63	0.77	0.39	0.25	0.62
141	461.7	737.0	17.16	0.73	....	....	0.37	0.36	0.60
142	466.6	154.5	17.41	0.77	1.05	0.95	0.51	0.26	0.77
143	469.1	665.8	16.74	1.01	....	....	0.41	0.61	1.01
144	471.6	978.4	17.21	0.86	....	....	0.52	0.34	0.85
145	477.2	181.6	17.41	0.66	1.03	0.86	0.42	0.24	0.59
146	477.3	39.3	14.40	0.62	0.49	0.99	0.42	0.21	0.60
147	479.9	311.8	12.64	0.59	0.67	0.67	0.36	0.22	0.55
148	481.1	749.6	10.85	0.54	0.28	0.86	0.34	0.20	0.51
149	486.6	181.2	17.48	0.73	....	....	0.44	0.29	0.68
150	491.1	412.1	15.79	0.74	0.83	1.03	0.43	0.31	0.75
151	493.5	22.6	16.85	0.85	....	....	0.34	0.51	0.58
152	494.2	319.5	17.32	0.82	0.97	0.23	0.32	0.50	0.71
153	494.9	249.3	14.08	1.16	1.31	1.61	0.68	0.49	1.02
154	495.4	775.5	16.35	0.70	0.14	1.12	0.44	0.25	0.64
155	496.8	887.3	15.09	1.01	....	1.88	0.58	0.43	0.91
156	498.5	730.8	17.85	....	....	....	....	0.47	0.71

Table 5. continued.

N	Xc	Yc	V	$Y-V$	$P-X$	$X-Y$	$Y-Z$	$Z-V$	$V-S$
157	500.6	500.2	15.36	0.94	1.16	1.47	0.49	0.46	0.86
158	501.2	200.4	17.59	....	....	....	....	....	0.56
159	502.4	894.8	15.17	0.61	0.32	1.04	0.38	0.23	0.59
160	503.1	913.3	16.35	1.03	....	....	0.35	0.68	1.08
161	512.7	794.0	16.06	0.99	....	1.55	0.56	0.42	0.86
162	513.3	198.2	16.62	0.82	0.95	0.96	0.43	0.39	0.70
163	513.8	823.3	17.78	0.86	....	....	....	....	0.67
164	515.8	623.5	16.76	0.87	....	....	0.54	0.33	0.74
165	515.9	936.0	17.13	0.67	....	....	0.38	0.28	0.63
166	517.7	91.9	17.48	....	....	....	....	0.34	0.81
167	518.3	356.8	16.88	0.61	....	1.14	0.36	0.25	0.66
168	519.9	412.4	16.54	0.73	0.67	0.89	0.25	0.48	0.64
169	521.9	807.2	17.71	....	....	....	....	....	0.89
170	522.4	223.7	17.36	1.14	....	0.90	0.65	0.49	0.85
171	524.6	257.3	16.62	1.07	....	....	0.66	0.41	1.02
172	524.7	795.6	17.80	....	....	....	....	....	0.67
173	526.7	137.8	17.54	0.61	....	....	0.35	0.26	0.72
174	527.7	528.1	14.22	1.57	....	1.89	1.13	0.44	1.56
175	536.3	231.6	17.59	....	....	....	....	0.60	0.96
176	536.8	980.5	17.17	0.94	....	....	0.54	0.40	0.81
177	537.0	798.5	16.55	0.87	....	1.62	0.43	0.44	0.80
178	543.0	100.4	17.42	....	....	....	....	0.56	0.84
179	546.2	63.6	15.94	0.83	....	1.34	0.42	0.41	0.80
180	546.5	936.4	17.50	....	....	....	....	0.58	0.78
181	549.8	826.2	11.95	1.11	1.23	1.85	0.58	0.53	1.05
182	553.1	759.1	16.29	0.85	....	1.60	0.42	0.43	0.83
183	553.5	371.4	17.58	....	....	....	....	....	0.75
184	554.8	313.0	17.70	0.76	....	....	....	....	0.70
185	555.3	461.6	17.63	0.95	....	....	0.59	0.36	0.73
186	555.6	211.7	11.87	....	....	....	....	....	....
187	561.5	253.9	15.18	0.61	0.69	0.71	0.41	0.19	0.59
188	561.8	272.1	12.34	....	....	....	....	....	....
189	566.7	434.5	11.89	0.66	0.69	0.81	0.40	0.25	0.63
190	567.6	368.1	15.82	0.74	0.41	1.10	0.47	0.28	0.66
191	569.5	168.6	17.19	0.61	....	....	0.38	0.24	0.75
192	570.3	956.3	16.22	0.75	....	1.33	0.38	0.37	0.68
193	576.1	652.4	17.75	....	....	....	....	....	0.86
194	579.4	910.6	15.61	0.77	0.48	1.34	0.45	0.32	0.73
195	584.6	996.9	14.20	0.57	0.31	0.98	0.36	0.21	0.53
196	585.6	603.4	17.53	0.84	....	....	....	....	0.76
197	586.8	648.1	17.42	0.82	....	....	0.49	0.34	0.61
198	587.8	237.6	15.61	0.63	0.69	0.70	0.39	0.23	0.56
199	590.0	742.1	16.51	0.86	....	....	0.51	0.35	0.66
200	592.7	419.4	16.69	0.84	0.56	0.84	0.35	0.49	0.66
201	594.7	13.5	16.58	1.24	....	0.94	0.45	0.78	0.10
202	596.9	275.9	17.45	0.80	....	....	....	....	0.86
203	597.1	618.3	16.38	0.89	....	1.66	0.46	0.44	0.81
204	601.6	919.1	16.91	0.77	0.33	1.12	0.51	0.26	0.65
205	602.4	479.6	17.32	1.01	....	....	0.48	0.53	0.78
206	606.6	63.3	13.18	0.68	0.68	0.98	0.42	0.26	0.66
207	606.9	799.7	13.64	0.99	0.74	1.74	0.57	0.43	0.87
208	611.7	293.8	16.80	0.70	....	1.15	0.46	0.24	0.72

Table 5. continued.

N	Xc	Yc	V	$Y-V$	$P-X$	$X-Y$	$Y-Z$	$Z-V$	$V-S$
209	613.0	778.8	17.47	0.63	....	1.26	0.34	0.29	0.68
210	615.9	455.5	17.87	....	....	....	....	....	0.57
211	616.9	63.6	16.13	0.69	0.78	0.83	0.43	0.26	0.70
212	621.8	792.1	17.72	....	....	....	....	....	0.78
213	626.2	551.9	16.70	0.78	....	1.17	0.47	0.31	0.68
214	632.0	60.3	12.76	0.83	0.87	1.14	0.52	0.31	0.78
215	633.5	444.3	15.91	0.74	0.63	0.81	0.40	0.35	0.60
216	636.0	909.0	16.16	0.28	0.43	0.62	0.19	0.09	0.26
217	637.1	765.9	17.30	0.75	....	....	0.39	0.37	0.70
218	637.6	1009.9	15.40	0.65	0.26	1.05	0.39	0.26	0.61
219	638.3	238.9	16.61	0.90	0.96	1.22	0.50	0.40	0.85
220	639.1	252.8	17.63	....	....	....	....	....	0.77
221	641.1	173.5	15.82	0.65	0.60	0.92	0.40	0.25	0.67
222	643.5	66.5	16.77	1.10	....	....	0.67	0.44	0.88
223	644.5	772.2	17.89	....	....	....	....	....	0.63
224	646.5	37.5	16.94	0.88	....	....	0.41	0.48	0.86
225	651.6	189.3	14.62	0.98	0.77	1.16	0.64	0.34	0.89
226	651.8	99.5	16.29	0.71	0.80	1.24	0.45	0.25	0.77
227	652.0	283.0	17.07	0.70	....	....	0.43	0.27	0.74
228	654.9	676.7	15.13	0.99	....	1.81	0.56	0.43	0.90
229	660.8	921.6	16.45	0.78	0.17	1.26	0.46	0.31	0.64
230	663.2	153.0	17.81	0.55	....	....	....	....	0.68
231	666.5	443.6	17.68	....	....	....	....	....	0.62
232	667.2	535.1	16.03	0.65	0.40	1.11	0.41	0.24	0.65
233	672.1	784.7	17.04	0.82	....	....	0.45	0.38	0.72
234	676.8	735.5	17.67	0.76	....	....	0.45	0.32	0.68
235	680.6	844.4	17.27	0.68	....	1.11	0.38	0.30	0.60
236	683.4	144.7	15.57	0.89	0.98	1.43	0.48	0.41	0.82
237	686.7	373.3	16.70	0.83	0.66	0.77	0.38	0.45	0.72
238	688.7	1005.9	15.12	0.63	0.29	1.01	0.39	0.23	0.59
239	689.2	279.5	16.42	0.86	....	....	0.48	0.38	0.83
240	692.2	567.5	15.10	0.99	0.77	1.77	0.56	0.43	0.89
241	694.5	205.1	13.77	0.67	0.64	0.96	0.39	0.28	0.68
242	694.8	294.9	17.47	0.74	....	....	0.39	0.36	0.60
243	696.9	473.3	15.10	0.72	0.77	1.00	0.34	0.38	0.65
244	700.9	74.7	14.21	0.63	0.68	0.81	0.40	0.23	0.61
245	705.1	853.4	16.89	0.80	....	....	0.45	0.35	0.65
246	705.9	764.8	17.16	0.82	....	....	0.40	0.42	0.82
247	706.4	549.9	17.50	....	....	....	....	0.27	0.72
248	709.7	800.9	16.38	0.66	....	1.09	0.36	0.29	0.59
249	711.0	404.9	15.62	1.02	1.00	1.39	0.60	0.42	0.90
250	711.1	567.5	16.22	0.92	....	1.51	0.57	0.35	0.85
251	711.5	1011.8	16.54	0.84	0.50	1.07	0.54	0.30	0.67
252	715.7	336.8	16.98	0.62	....	1.06	0.33	0.29	0.65
253	715.9	28.6	16.09	....	....	1.00	0.61	....	....
254	718.5	112.6	16.12	0.75	0.65	0.76	0.43	0.32	0.66
255	722.2	765.7	16.15	0.97	....	1.56	0.59	0.38	0.89
256	726.0	151.1	15.22	0.96	1.08	1.34	0.59	0.37	0.86
257	730.2	330.5	14.98	0.66	0.41	1.15	0.38	0.27	0.64
258	731.3	973.9	17.76	....	....	....	....	....	1.27
259	733.2	263.6	13.39	0.72	0.72	0.90	0.44	0.28	0.68
260	734.1	26.8	17.38	0.88	....	....	0.53	0.35	0.51
261	736.7	178.2	17.02	0.76	0.89	0.75	0.35	0.42	0.66
262	738.8	461.9	16.12	0.77	0.69	0.89	0.43	0.34	0.64
263	739.9	557.1	17.10	0.77	....	....	0.52	0.25	0.68
264	740.0	421.1	17.65	....	....	....	....	0.27	0.80
265	742.0	109.8	14.34	1.28	1.42	1.85	0.78	0.51	0.98
266	743.7	505.0	16.53	0.89	0.77	0.88	0.46	0.43	0.71
267	746.7	697.2	16.22	0.69	0.39	1.25	0.42	0.27	0.69
268	754.8	797.6	17.26	0.87	....	....	0.28	0.59	0.96
269	755.8	958.3	16.16	0.68	0.17	1.15	0.37	0.32	0.59
270	760.3	597.9	17.61	....	....	....	....	0.47	0.82
271	762.1	274.6	16.89	0.71	....	....	0.41	0.29	0.67
272	762.2	19.7	17.01	....	....	....	....	0.73	0.27
273	762.4	416.9	12.55	1.05	1.46	1.83	0.57	0.48	1.02
274	762.6	622.2	16.00	0.74	0.34	1.18	0.41	0.33	0.66
275	771.7	784.4	14.70	0.68	0.35	1.20	0.39	0.29	0.65
276	774.1	902.6	17.14	0.68	....	....	0.39	0.30	0.66
277	774.4	598.1	15.38	0.65	0.30	1.04	0.40	0.24	0.63
278	780.6	308.2	16.57	0.81	....	1.26	0.48	0.32	0.77
279	781.5	481.6	13.16	0.61	0.65	0.78	0.37	0.24	0.58
280	782.3	515.9	14.24	0.97	0.68	1.68	0.57	0.41	0.87
281	783.4	963.3	17.07	0.68	....	1.19	0.45	0.23	0.75
282	786.6	551.8	16.37	0.76	....	1.22	0.45	0.31	0.74
283	788.9	207.8	16.56	0.74	0.60	1.06	0.47	0.27	0.73
284	792.6	454.3	17.40	0.77	....	....	0.44	0.33	0.59
285	794.4	52.9	17.31	0.75	....	0.96	0.43	0.32	0.70
286	794.9	762.3	17.73	0.69	....	....	....	....	0.83
287	795.9	1022.8	13.70	0.96	....	1.42	....	....	0.72
288	797.2	253.9	17.69	....	....	....	....	....	0.76
289	798.3	794.0	17.04	0.72	....	....	0.38	0.34	0.64
290	800.0	267.3	17.25	0.65	....	....	0.34	0.31	0.66
291	800.1	599.2	16.39	0.73	0.41	1.13	0.43	0.30	0.64
292	802.5	480.2	17.36	1.17	....	0.60	0.45	0.72	0.80
293	803.7	146.8	17.46	0.54	....	1.09	0.37	0.17	0.81
294	805.1	407.0	14.36	0.58	0.63	0.83	0.35	0.23	0.50
295	806.7	232.7	16.46	0.75	0.26	1.07	0.51	0.24	0.66
296	810.3	487.2	15.37	1.16	....	2.09	0.62	0.54	1.01
297	810.4	158.2	17.16	0.80	....	1.16	0.40	0.41	0.87
298	815.8	851.6	15.98	0.68	0.23	1.09	0.44	0.25	0.66
299	819.0	817.2	16.90	0.84	....	....	0.56	0.28	0.76
300	820.5	556.1	16.28	0.79	....	1.55	0.37	0.42	0.80
301	821.9	840.4	16.59	0.65	0.16	1.05	0.44	0.22	0.65
302	822.6	282.4	15.67	0.63	0.36	1.05	0.39	0.24	0.62
303	823.6	773.9	17.71	0.58	....	....	0.32	0.26	0.61
304	825.1	205.6	17.20	0.71	....	1.20	0.50	0.21	0.68
305	827.5	24.6	16.71	0.42	0.70	0.49	0.25	0.17	0.22
306	835.3	233.9	16.48	0.77	....	1.07	0.45	0.31	0.64
307	841.1	98.5	16.47	0.79	....	1.56	0.41	0.38	0.78
308	845.5	750.7	15.39	0.98	....	1.73	0.55	0.43	0.90
309	845.9	910.6	16.23	0.63	0.22	0.99	0.39	0.24	0.58
310	852.3	950.1	12.80	0.58	0.70	0.76	0.32	0.26	0.53
311	854.5	151.7	16.44	0.75	0.68	1.00	0.30	0.45	0.65
312	862.5	402.9	16.38	0.89	0.64	0.79	0.47	0.42	0.69
313	866.0	864.2	17.18	0.71	....	1.08	0.39	0.32	0.65

Table 5. continued.

N	*Xc*	*Yc*	*V*	*Y*−*V*	*P*−*X*	*X*−*Y*	*Y*−*Z*	*Z*−*V*	*V*−*S*
314	867.1	199.5	16.20	0.71	....	0.97	0.47	0.24	0.59
315	872.0	57.7	17.51	0.68	....	....	....	....	0.73
316	874.4	455.8	17.71	0.94	....	....	....	....	0.71
317	876.9	205.1	17.59	0.62	....	....	0.34	0.28	0.53
318	878.7	71.5	15.41	0.81	0.79	1.11	0.45	0.36	0.85
319	884.1	408.8	14.98	....	....	....	....	....	....
320	886.0	740.2	16.94	0.94	....	....	0.30	0.64	0.86
321	889.7	969.6	16.94	0.72	....	1.31	0.38	0.34	0.72
322	892.3	143.2	17.12	0.85	0.49	0.99	0.47	0.38	0.76
323	894.3	478.9	15.29	0.81	1.01	1.19	0.37	0.44	0.84
324	896.8	229.4	16.38	0.66	0.78	0.88	0.38	0.28	0.68
325	897.1	153.6	16.21	0.81	0.63	1.10	0.40	0.41	0.69
326	904.5	712.8	16.93	0.65	0.24	1.02	0.42	0.22	0.65
327	908.1	263.3	15.24	0.81	1.01	1.39	0.40	0.41	0.83
328	908.7	840.9	15.64	0.71	0.45	1.24	0.42	0.29	0.65
329	909.7	744.8	17.44	0.73	....	....	0.36	0.37	0.67
330	910.7	118.7	18.00	....	....	....	....	....	0.82
331	911.0	805.2	16.76	0.72	0.38	1.11	0.37	0.35	0.59
332	912.6	386.0	17.62	0.83	....	....	....	....	0.89
333	915.8	337.9	17.47	0.82	....	....	0.49	0.33	0.85
334	917.2	1008.8	17.53	0.80	....	....	0.39	0.41	0.82
335	919.1	318.9	15.31	1.16	0.83	1.33	0.47	0.69	0.90
336	922.5	249.5	17.28	0.72	0.79	1.01	0.37	0.35	0.76
337	925.2	307.2	16.51	0.69	0.77	1.12	0.40	0.29	0.73
338	927.6	899.5	16.92	0.86	....	....	0.37	0.48	0.77
339	933.9	353.1	17.11	1.27	0.57	0.54	0.86	0.41	0.55
340	934.9	866.2	15.47	0.63	0.36	1.05	0.40	0.23	0.61
341	935.8	25.0	14.67	1.05	0.82	1.67	0.59	0.45	0.80
342	939.4	107.9	17.76	0.80	....	....	....	....	0.70
343	939.8	681.4	17.00	0.65	0.22	1.15	0.35	0.30	0.65
344	942.6	99.0	16.72	0.75	0.28	1.07	0.48	0.27	0.62
345	946.7	146.6	16.30	0.80	....	1.50	0.49	0.32	0.83
346	949.7	947.1	17.05	0.82	....	....	0.51	0.31	0.69
347	950.7	328.8	17.65	0.77	....	....	0.45	0.32	0.71
348	956.5	173.7	16.87	0.61	....	1.07	0.36	0.25	0.63
349	959.6	54.8	15.61	0.89	0.77	1.36	0.55	0.34	0.83
350	960.6	1003.1	17.00	0.91	....	....	0.55	0.36	0.88
351	964.3	143.4	17.35	0.66	....	....	0.46	0.20	0.78
352	968.1	898.2	16.49	0.94	....	1.44	0.53	0.41	0.80
353	968.3	455.7	17.40	0.67	....	1.13	0.29	0.38	0.64
354	969.9	939.5	17.05	0.88	....	....	0.59	0.29	0.63
355	971.2	56.5	15.91	0.70	0.48	1.23	0.44	0.26	0.71
356	972.1	15.3	16.69	1.32	....	....	0.34	0.98	0.28
357	974.4	410.2	15.88	0.72	0.49	1.23	0.41	0.31	0.67
358	991.6	703.1	16.15	0.70	0.53	1.35	0.36	0.34	0.70
359	991.8	442.3	17.51	0.63	....	....	0.31	0.32	0.67
360	992.9	130.9	17.07	0.69	....	1.05	0.48	0.21	0.61
361	994.3	957.3	17.13	....	....	....	....	0.40	0.65
362	999.2	313.4	17.76	....	....	....	....	0.31	0.70
363	1000.8	798.1	16.27	0.89	....	....	0.54	0.35	0.80
364	1001.1	221.7	10.64	0.61	0.67	0.87	0.38	0.23	0.56
365	1003.2	810.3	15.58	1.09	....	1.93	0.64	0.45	0.94
366	1003.6	171.4	15.69	0.64	0.46	1.05	0.42	0.22	0.63

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