QC Analysis of Large Rods for FCalchik Module

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The goal of this analysis was to determine if the copper rods for the FCalchik were machined to the desired specifications. The procedures for making the measurements were derived from previous QC tolerance studies done by Igor Koruga (1999-2000), Joshua Ruder, and Charissa Fuhrmann (2002). The following write-up follows that of Joshua Ruder and Charissa Fuhrmann, because this study follows their work closely.

Engineering plans for the FCalchik rods call for a diameter [D] of 5.012mm (0.197") and a rod length [L] of 50.8mm (2").

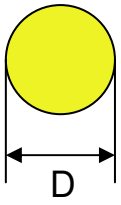


Figure 1 – Rod Cross Section

A Mitutoyo 0-1" .0001" micrometer, model number 202-204, was used to take the D measurement of the rods. A 1-2" .0001" micrometer, model number 202-208, was used to measure L.

The 202-204 micrometer was held in place on a stand using test tube clamps. The micrometer was then adjusted to the diameter of the rod. Because the rods were short, this freed up one hand to hold the rod in the correct orientation while the other adjusted the micrometer. The 202-208 micrometer was held in hand while measuring the length. A small scratch was placed on the pin end of each rod for orientation purposes. All 18 rods machined were measured.

Each rod was measured at three (3) points: at each end and the middle. At each of these positions two orientations were measured: the original orientation and second orientation 90 degrees from the first. Hence, six measurements were taken on each rod. The naming convention is as follows. A form of X.YZ is used. Where X indicates what is being measured, in this case the outer diameter [D]. The YZ indicates position [Y] and orientation [Z} of the measurement. Data points with odd Z subscripts are normal in orientation to data points with even Z subscripts. For this system, position 1 (Y = 1) refers to the pin hole end of the rod. Also orientation one (Z = 1) refers to the scratch on the pinhole end of the rod being normal to the plane of measurement. For example, D11 means the diameter at position one with orientation one was measured; D22 means that the diameter at position two with orientation two was measured (its normal orientation to D11). See Figure 2.

Figure 2 – Measurement Positions

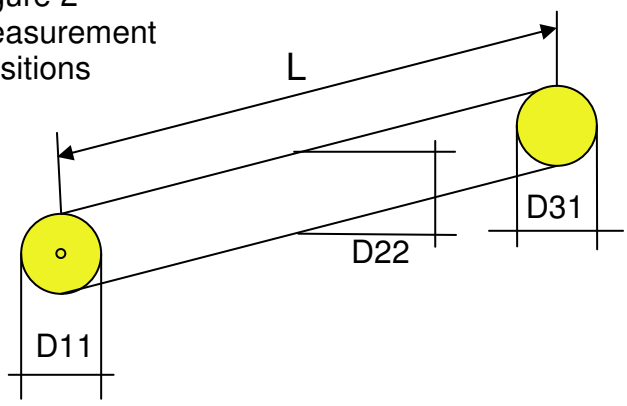


Table 1 – Raw Diameter and Length Measurements (in)

Measurements D11 and D12 are on the pin hole side
All measurements in inches

Rod #	D11	D12	D21	D22	D31	D32	L
1	0.1972	0.1970	0.1974	0.1974	0.1973	0.1972	1.9668
2	0.1994	0.1994	0.1988	0.1987	0.1974	0.1976	1.9667
3	0.1974	0.1975	0.1974	0.1972	0.1970	0.1970	1.9700
4	0.1976	0.1975	0.1974	0.1973	0.1977	0.1977	1.9661
5	0.1986	0.1986	0.1981	0.1980	0.1971	0.1971	1.9665
6	0.1972	0.1972	0.1972	0.1971	0.1965	0.1965	1.9662
7	0.1976	0.1975	0.1975	0.1975	0.1971	0.1970	1.9661
8	0.1986	0.1986	0.1983	0.1982	0.1974	0.1973	1.9667
9	0.1988	0.1988	0.1983	0.1981	0.1973	0.1973	1.9666
10	0.1988	0.1987	0.1983	0.1982	0.1974	0.1974	1.9647
11	0.1966	0.1966	0.1969	0.1972	0.1970	0.1970	1.9654
12	0.1970	0.1970	0.1971	0.1970	0.1963	0.1963	1.9637
13	0.1976	0.1976	0.1974	0.1972	0.1969	0.1966	1.9666
14	0.1981	0.1981	0.1976	0.1974	0.1965	0.1964	1.9649
15	0.1970	0.1970	0.1969	0.1969	0.1961	0.1961	1.9679
16	0.1964	0.1963	0.1967	0.1967	0.1970	0.1969	1.9651
17	0.1975	0.1974	0.1974	0.1973	0.1962	0.1962	1.9651
18	0.1972	0.1972	0.1971	0.1971	0.1965	0.1965	1.9665

Table 2 – Raw Reliability Measurements (in)

Repeatability of Measurements of Rods
All measurements in inches

Measurement	D11	D12	D21	D22	D31	D32	L
1	0.1966	0.1965	0.1967	0.1967	0.1969	0.1968	1.9649
2	0.1965	0.1964	0.1969	0.1969	0.1968	0.1967	1.9651
3	0.1966	0.1965	0.1968	0.1968	0.1968	0.1967	1.9651
4	0.1966	0.1965	0.1970	0.1970	0.1970	0.1969	1.9652
5	0.1965	0.1965	0.1970	0.1970	0.1969	0.1969	1.9650
6	0.1964	0.1964	0.1970	0.1969	0.1968	0.1968	1.9652
7	0.1965	0.1965	0.1969	0.1969	0.1968	0.1968	1.9652
8	0.1966	0.1965	0.1970	0.1970	0.1968	0.1968	1.9653
9	0.1965	0.1965	0.1970	0.1971	0.1969	0.1968	1.9653
10	0.1965	0.1964	0.1970	0.1970	0.1968	0.1968	1.9653
11	0.1966	0.1965	0.1969	0.1969	0.1969	0.1969	1.9653
12	0.1966	0.1965	0.1970	0.1970	0.1968	0.1968	1.9652
13	0.1965	0.1965	0.1970	0.1970	0.1969	0.1968	1.9653
14	0.1965	0.1964	0.1970	0.1970	0.1969	0.1969	1.9652
15	0.1966	0.1964	0.1970	0.1969	0.1968	0.1968	1.9652
16	0.1966	0.1965	0.1969	0.1969	0.1968	0.1968	1.9653
17	0.1966	0.1965	0.1970	0.1970	0.1969	0.1969	1.9651
18	0.1965	0.1965	0.1969	0.1969	0.1968	0.1968	1.9652
19	0.1965	0.1965	0.1969	0.1969	0.1968	0.1968	1.9653
20	0.1966	0.1965	0.1970	0.1970	0.1968	0.1968	1.9653

Table 3 – Adjusted Rod Diameter and Length (mm)

Measurement D11 and D12 are on the pin hole side
All measurements are in mm

Rod #	D11	D12	D21	D22	D31	D32	L
1	5.0089	5.0038	5.0140	5.0140	5.0114	5.0089	49.9567
2	5.0648	5.0648	5.0495	5.0470	5.0140	5.0190	49.9542
3	5.0140	5.0165	5.0140	5.0089	5.0038	5.0038	50.0380
4	5.0190	5.0165	5.0140	5.0114	5.0216	5.0216	49.9389
5	5.0444	5.0444	5.0317	5.0292	5.0063	5.0063	49.9491
6	5.0089	5.0089	5.0089	5.0063	4.9911	4.9911	49.9415
7	5.0190	5.0165	5.0165	5.0165	5.0063	5.0038	49.9389
8	5.0444	5.0444	5.0368	5.0343	5.0140	5.0114	49.9542
9	5.0495	5.0495	5.0368	5.0317	5.0114	5.0114	49.9516
10	5.0495	5.0470	5.0368	5.0343	5.0140	5.0140	49.9034
11	4.9936	4.9936	5.0013	5.0089	5.0038	5.0038	49.9212
12	5.0038	5.0038	5.0063	5.0038	4.9860	4.9860	49.8780
13	5.0190	5.0190	5.0140	5.0089	5.0013	4.9936	49.9516
14	5.0317	5.0317	5.0190	5.0140	4.9911	4.9886	49.9085
15	5.0038	5.0038	5.0013	5.0013	4.9809	4.9809	49.9847
16	4.9886	4.9860	4.9962	4.9962	5.0038	5.0013	49.9135
17	5.0165	5.0140	5.0140	5.0114	4.9835	4.9835	49.9135
18	5.0089	5.0089	5.0063	5.0063	4.9911	4.9911	49.9491

Table 4 – Adjusted Reliability Measurements (mm)

Repeatability of Measurements of Rods
All measurements in mm

Measurement	D11	D12	D21	D22	D31	D32	L
1	4.9936	4.9911	4.9962	4.9962	5.0013	4.9987	49.9085
2	4.9911	4.9886	5.0013	5.0013	4.9987	4.9962	49.9135
3	4.9936	4.9911	4.9987	4.9987	4.9987	4.9962	49.9135
4	4.9936	4.9911	5.0038	5.0038	5.0038	5.0013	49.9161
5	4.9911	4.9911	5.0038	5.0038	5.0013	5.0013	49.9110
6	4.9886	4.9886	5.0038	5.0013	4.9987	4.9987	49.9161
7	4.9911	4.9911	5.0013	5.0013	4.9987	4.9987	49.9161
8	4.9936	4.9911	5.0038	5.0038	4.9987	4.9987	49.9186
9	4.9911	4.9911	5.0038	5.0063	5.0013	4.9987	49.9186
10	4.9911	4.9886	5.0038	5.0038	4.9987	4.9987	49.9186
11	4.9936	4.9911	5.0013	5.0013	5.0013	5.0013	49.9186
12	4.9936	4.9911	5.0038	5.0038	4.9987	4.9987	49.9161
13	4.9911	4.9911	5.0038	5.0038	5.0013	4.9987	49.9186
14	4.9911	4.9886	5.0038	5.0038	5.0013	5.0013	49.9161
15	4.9936	4.9886	5.0038	5.0013	4.9987	4.9987	49.9161
16	4.9936	4.9911	5.0013	5.0013	4.9987	4.9987	49.9186
17	4.9936	4.9911	5.0038	5.0038	5.0013	5.0013	49.9135
18	4.9911	4.9911	5.0013	5.0013	4.9987	4.9987	49.9161
19	4.9911	4.9911	5.0013	5.0013	4.9987	4.9987	49.9186
20	4.9936	4.9911	5.0038	5.0038	4.9987	4.9987	49.9186

Table 5 – Individual Rod Statistics (mm)

All measurements in mm

Rod #	Max D	Min D	Avg. D	Std. Dev D
1	5.0140	5.0038	5.0102	0.0035
2	5.0648	5.0140	5.0432	0.0201
3	5.0165	5.0038	5.0102	0.0050
4	5.0216	5.0114	5.0173	0.0038
5	5.0444	5.0063	5.0271	0.0158
6	5.0089	4.9911	5.0025	0.0081
7	5.0190	5.0038	5.0131	0.0058
8	5.0444	5.0114	5.0309	0.0134
9	5.0495	5.0114	5.0317	0.0157
10	5.0495	5.0140	5.0326	0.0142
11	5.0089	4.9936	5.0008	0.0056
12	5.0063	4.9860	4.9983	0.0087
13	5.0190	4.9936	5.0093	0.0093
14	5.0317	4.9886	5.0127	0.0174
15	5.0038	4.9809	4.9953	0.0102
16	5.0038	4.9860	4.9953	0.0063
17	5.0165	4.9835	5.0038	0.0144
18	5.0089	4.9911	5.0021	0.0079

Table 6 – Compiled Rod Statistics (mm)

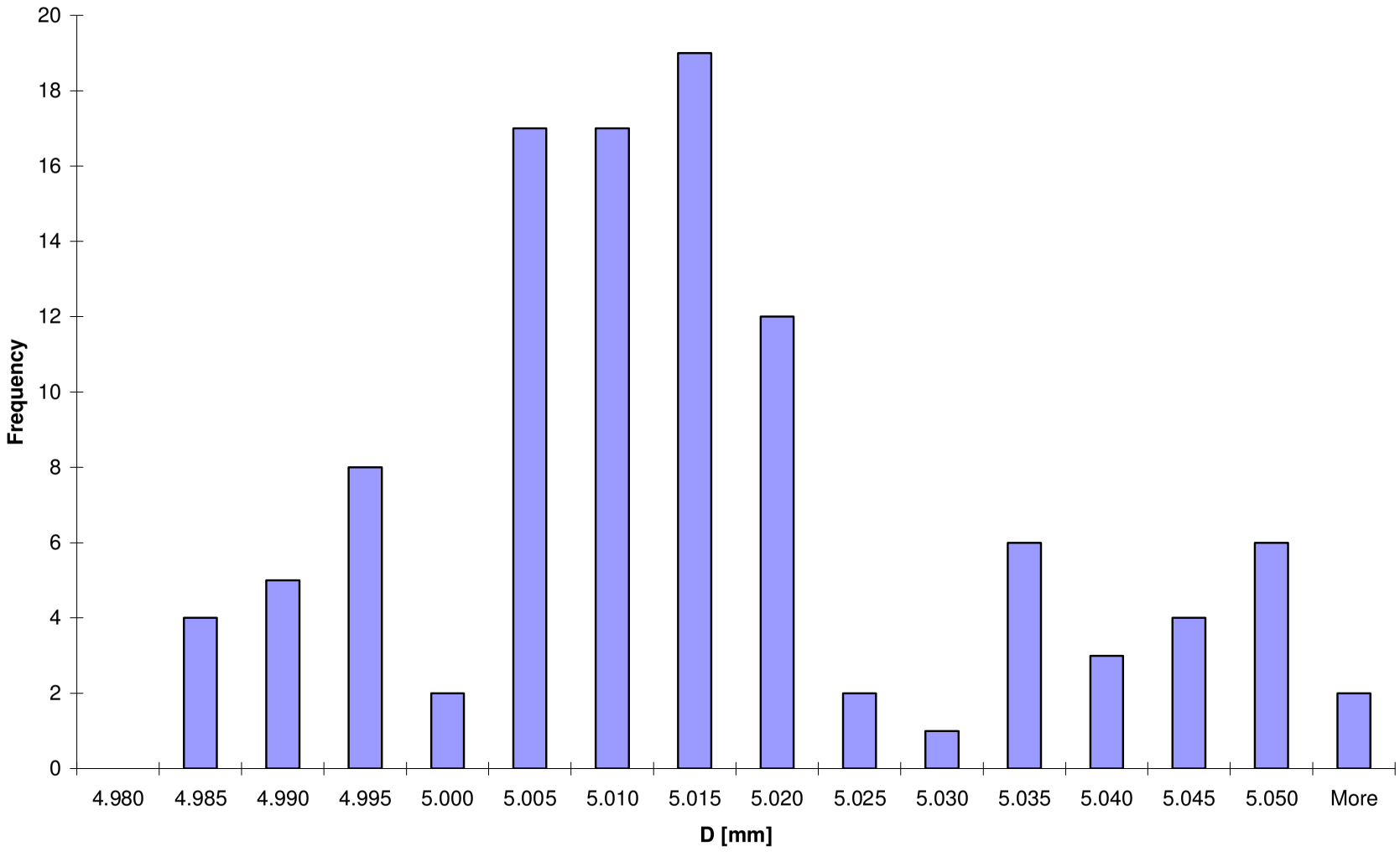
All measurements in mm

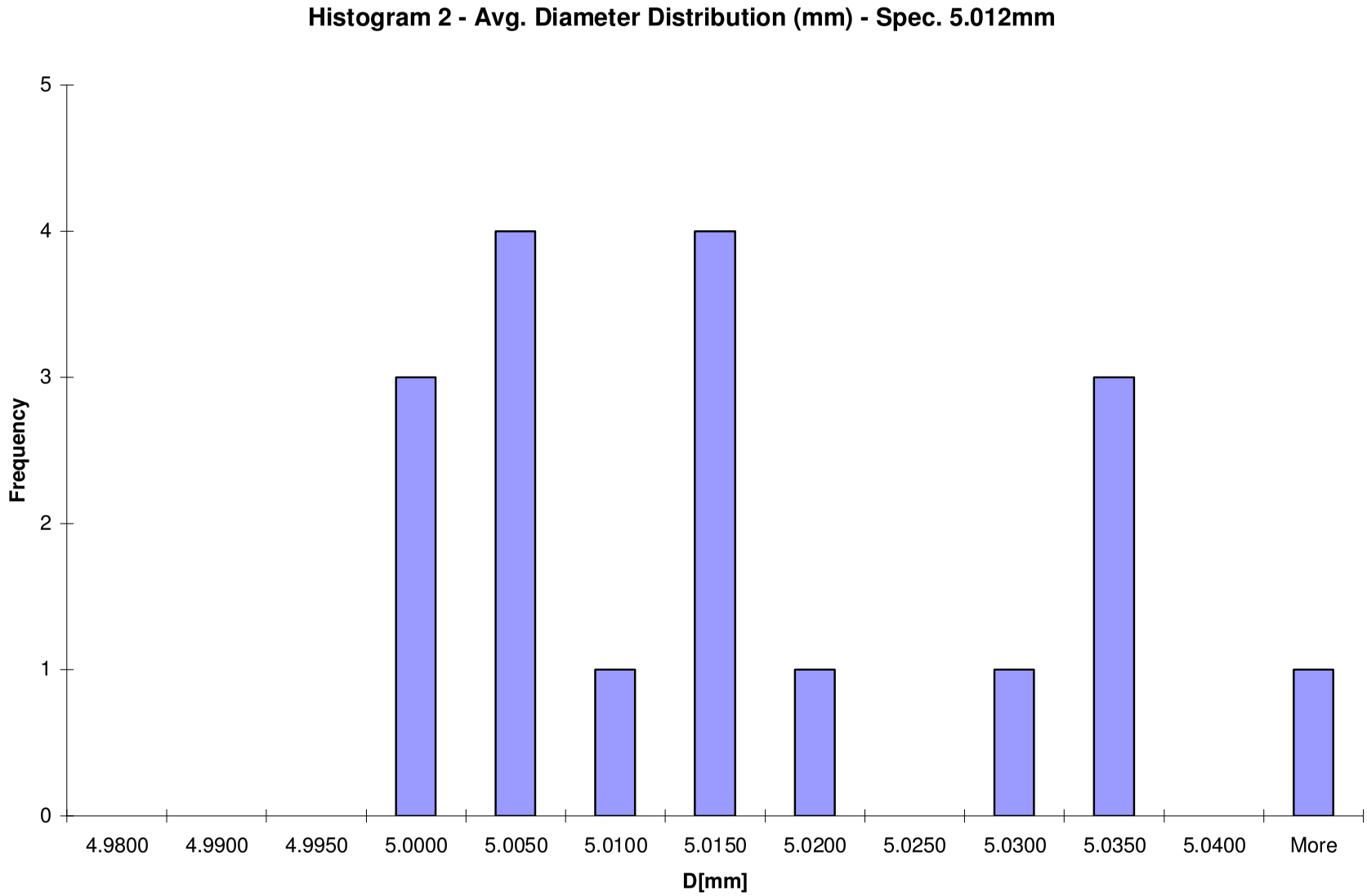
	Max D	Min D	Avg. D	RMS
Diameter	5.0648	4.9809	5.0131	0.0180

	Max L	Min L	Avg L	RMS
Length	50.0380	49.8780	49.9415	0.0338

Reliability	Max	Min	Avg.	Std. Dev.
D11	4.9936	4.9886	4.9922	0.0015
D12	4.9911	4.9886	4.9905	0.0011
D21	5.0038	4.9962	5.0024	0.0020
D22	5.0063	4.9962	5.0023	0.0022
D31	5.0038	4.9987	4.9999	0.0015
D32	5.0013	4.9962	4.9991	0.0015
L	49.9186	49.9085	49.9161	0.0028

Histogram 1 - Diameter Distributions (mm) - Spec. 5.012mm




Histogram 2 - Avg. Diameter Distribution (mm) - Spec. 5.012mm
Frequency
0
1
2
3
4
5
4.9800
4.9900
4.9950
5.0000
5.0050
5.0100
5.0150
5.0200
5.0250
5.0300
5.0350
5.0400
More
D[mm]

Histogram 3 - Length Distribution (mm) - Spec. 2" = 50.8mm

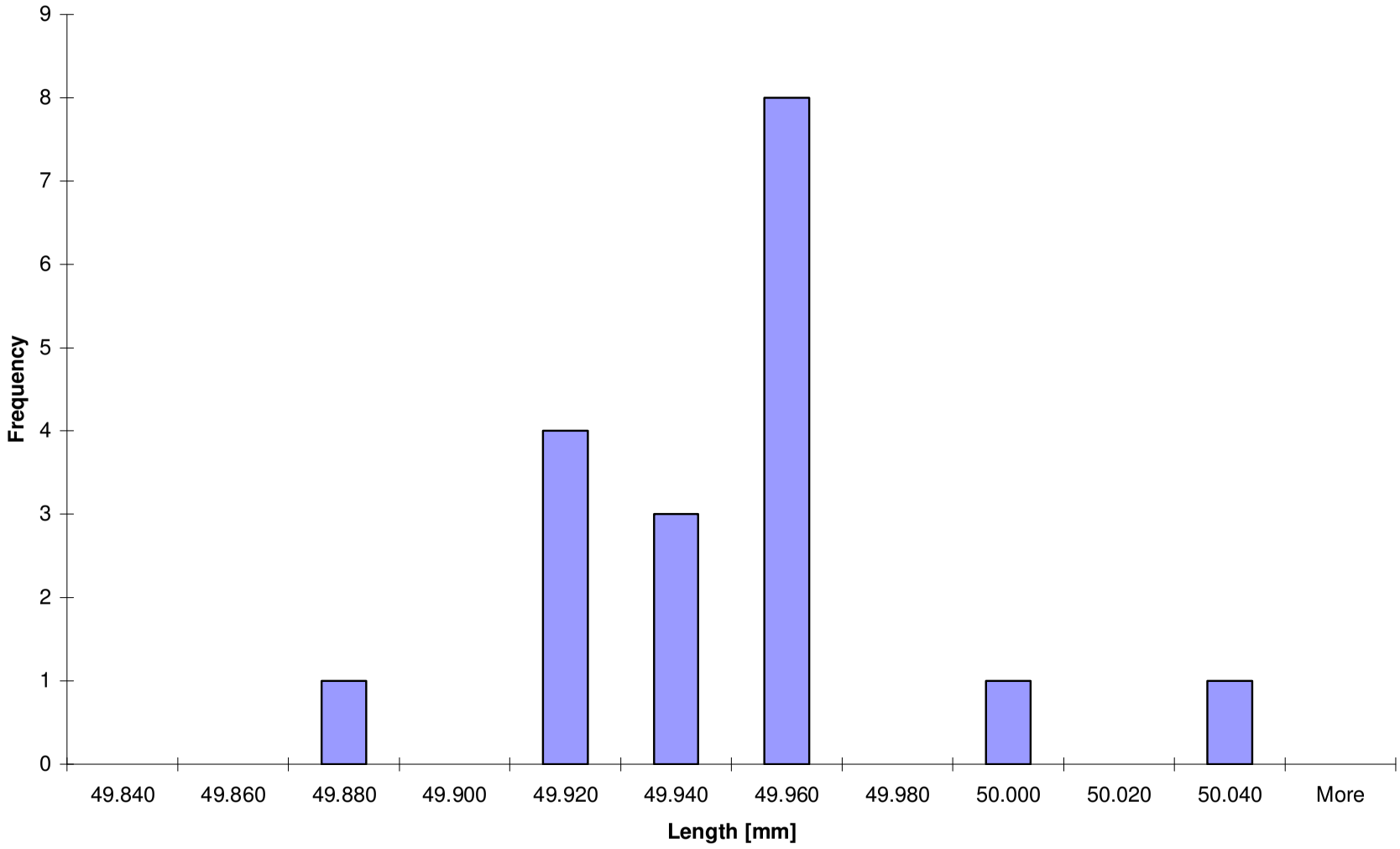


Table 1 –

This table is a compellation of the raw data, taken 5/31/2006, of the diameter and length of the rods. All measurements are in inches. The measurements were taken using the above mentioned micrometer. Not adjustments have been made to the data.

Table 2 –

This table is a compellation of the raw data taken 6/02/2006. It is the measure of the reliability of the diameter and length measurement process. A rod was chosen at random, and the diameter and length measurements were repeated 20 times. Measurements were taken using the above mentioned micrometer. All measurements are in inches and no adjustments to the data have been made.

Table 3 –

This table features the data from Table 1 converted into millimeters.

Table 4 –

This table contains the data from Table 2 converted into millimeters.

Table 5 –

For this table, statistics regarding the measurements of the individual rods are recorded. The maximum, minimum, and average measurement of each rod's diameter is recorded. The standard deviation was computed using the STDEVP function in Microsoft Excel. All measurements are in mm.

Table 6 –

This table contains statistics compiled from all the measurements on the rods from Table 3. The maximum rod diameter is found using Microsoft Excel's MAX function. The minimum diameter used the MIN function, and the average diameter used the AVERAGE function. The RMS value is found by taking the square root or the variance of all the data. The variance is computed by using the VARP function in Excel. The reliability statistics are taken from Table 4. Maximum, minimum, average and standard deviation are all calculated in Excel using the same methods as above. All values are in mm.

Histogram 1 –

This histogram shows the distribution of rod diameters. It includes all diameter measurements recorded in Table 3. All values fall within +1.05% and -0.62% of the manufacturing plans of 5.012mm. All values in are in mm.

Histogram 2 –

This histogram shows the distribution of the average rod diameters. It includes the diameters from Table 5. All values are in mm.

Histogram 3 –

Histogram 3 shows the distribution of rod lengths. It includes all length measurements from Table 3. All values are shorter than the 50.8mm value quoted in the plans, but all fall within 1.8% of the 50.8mm value. All values are in mm.

Conclusion

It was found that the rods were not manufactured to the engineering plans of 5.012mm diameter. However all rods fell within a +1.05% to -0.62% range. It was also found that all rods were made shorter than the 50.8mm (2") quoted length. All rods were within 1.8% of being 50.8mm long.