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Oak Ridge National Laboratory

Qualification of Mitutoyo RA-2200 Roundness Tester Measuring Instrument for Clad Vent Set Cup Roundness and Flatness Inspections

B. Friske
G. Ulrich
D. Freeman
K. Sheffield
B. Sizemore

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Radioisotope Power Systems Special Component Manufacturing and Testing Program
Materials Science and Technology Division

QUALIFICATION OF MITUTOYO RA-2200 ROUNDNESS TESTER MEASURING INSTRUMENT FOR CLAD VENT SET CUP ROUNDNESS AND FLATNESS INSPECTIONS

Brian Friske
George Ulrich
Dean Freeman
Kenneth Sheffield
Brian Sizemore

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CVS	Clad Vent Set

1. INTRODUCTION

Roundness (or circularity) and flatness measurements are made as part of the dimensional inspection process to certify that iridium alloy Clad Vent Set (CVS) cups meet the dimensional requirements of Iridium Alloy Cup Drawing M2D920101A005, Rev. 4 (see Figure 1). A Mahr Federal (Providence, RI) MarForm MMQ 400 Formtester is specified in the cup inspection Procedure GPHS-C-3624/25, Rev. 25 for roundness (dimension 16) and flatness (dimension 17). The Mahr Federal (Providence, RI) MarForm MMQ 400 Formtester stopped functioning in 2019. A new Mitutoyo RA-2200 Roundness Tester was purchased to replace the MMQ 400. Evaluations were conducted to qualify the new RA-2200 for CVS cup dimensional inspection work. The criterion for qualification was to ensure that the new RA-2200 instrument would yield roundness and flatness inspection results equivalent to or better than the predecessor MMQ 400 instrument.

2. EVALUATION OF ROUNDNESS AND FLATNESS STANDARDS

The first part of the qualification evaluations consisted of roundness and flatness measurements (10 of both measurements on each of 3 days by the primary inspector and backup inspector) of standards for roundness (Precision Test Ball A000447) and flatness (Optical Flat A000103). The same standards were used when the predecessor MMQ 400 instrument was qualified in 2009 (Ulrich, Walls, & Wright, 2009). A stylus ball diameter of 1.5-mm with stylus arm length of 60-mm was used for this test. The roundness measurements of the Precision Test Ball A000447 standard is shown in Figure 2 and summarized in Table 1. The flatness measurements of the Optical Flat A000103 standard are shown in Figure 3 and summarized in Table 2. The roundness standard was certified by an outside laboratory to be out-of-round 0.05-µm with an expanded uncertainty (k=2) of 0.025-µm. The flatness standard was certified by a different outside laboratory to be out-of-flat 0.05-µm with an expanded uncertainty (k=2) of 0.05-µm.

A comparison of the roundness, Figure 2 and Table 1, and flatness, Figure 3 and Table 2, results between two inspectors taking ten measurements each day for three days indicates that the Mitutoyo RA-2200 purchased in 2020 is indeed equivalent to or better than the old MarForm MMQ 400 Formtester it replaced. The fluctuations in the data are most likely reflective of the process capabilities. Other possible sources of these fluctuations were noted in the previous roundness and flatness qualification effort (Ulrich, Walls, & Wright, 2009).

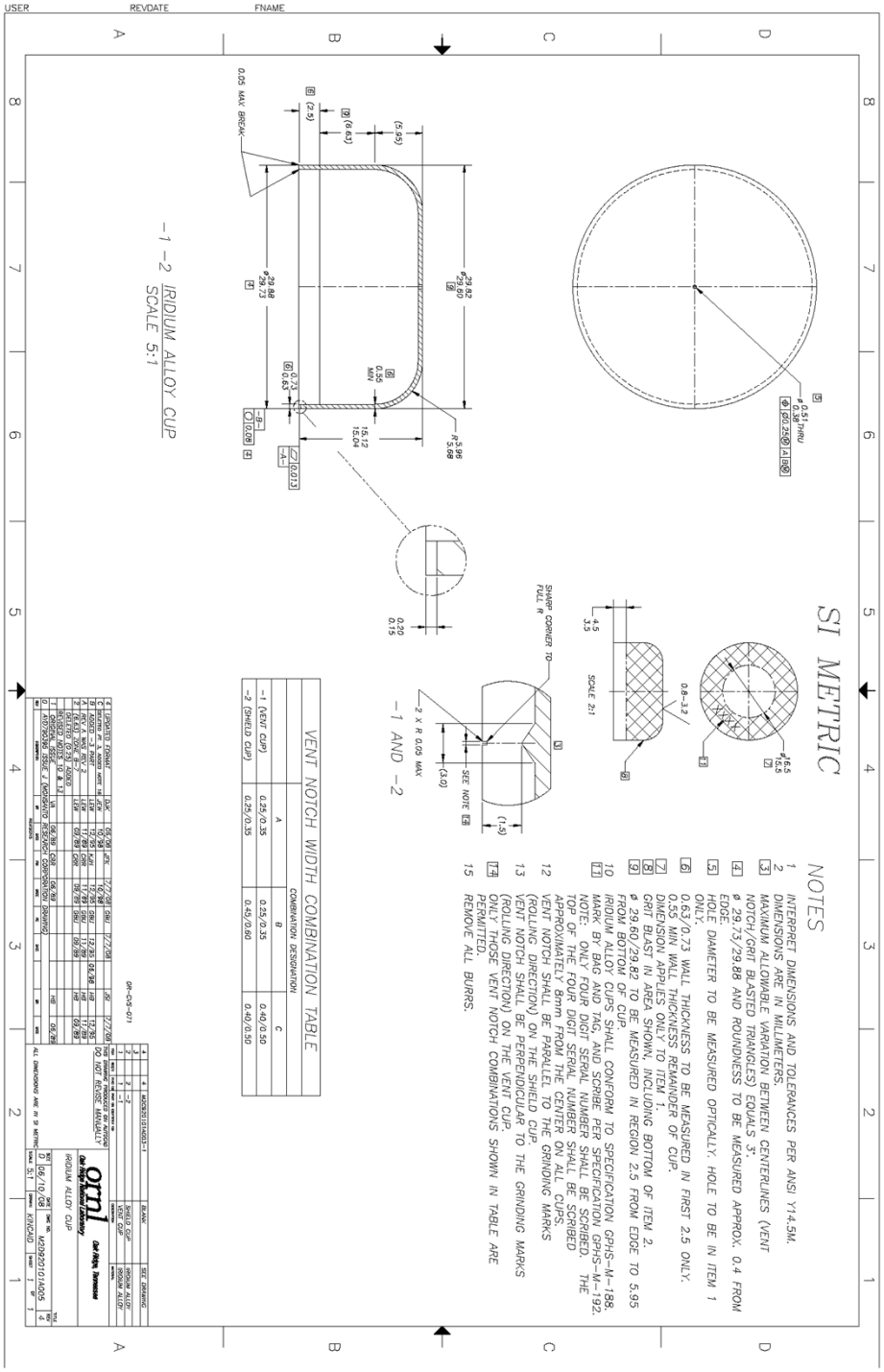

Figure 1. Iridium Alloy Cup Drawing

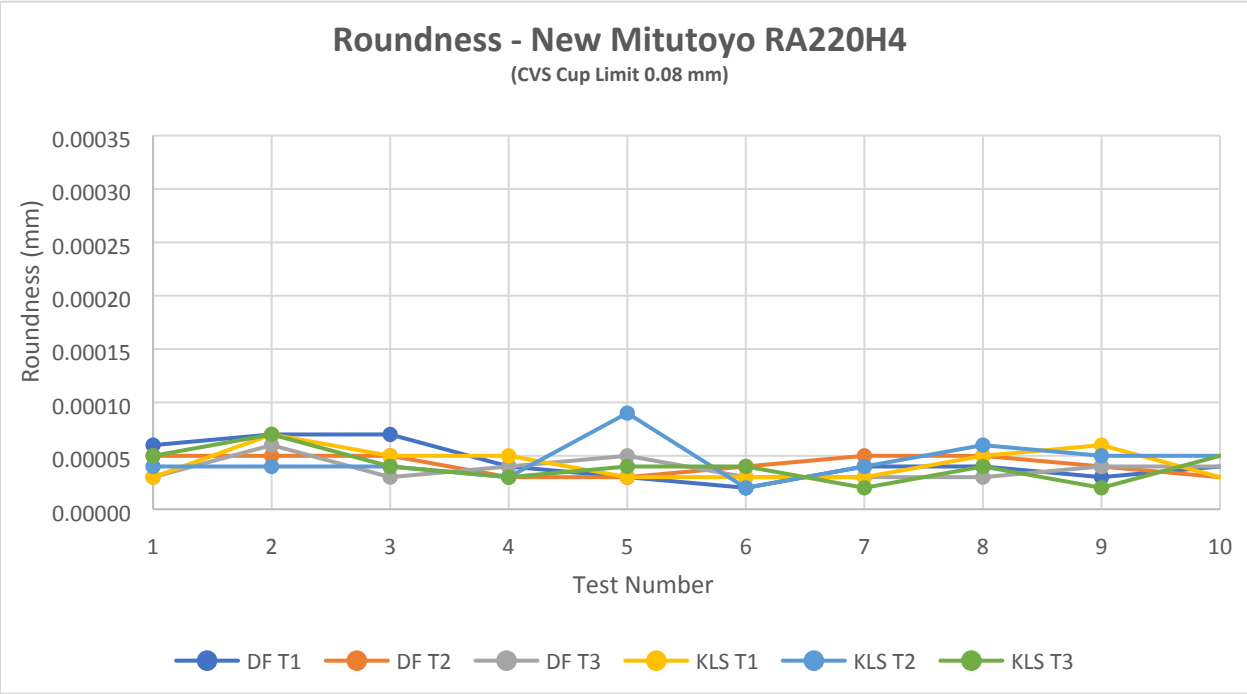

Figure 2. Roundness measurements of Precision Test Ball A000447 using Mitutoyo RA-2200 Roundness Machine with 1.5-mm ball. Two inspectors (DF and KLS) completed ten tests each day for three different days (T1, T2, and T3).

Table 1. New Mitutoyo RA-2200 and Predecessor MMQ 400 Roundness Precision Test Ball A000447 Measurements (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.00004	0.00004	0.00010
Standard deviation	0.000013	0.000016	0.00009
RSD (SD/Av) x100	30	37	87
Maximum	0.00007	0.00009	0.00032
Minimum	0.00002	0.00002	0.00004
Range	0.00004	0.00004	0.00028

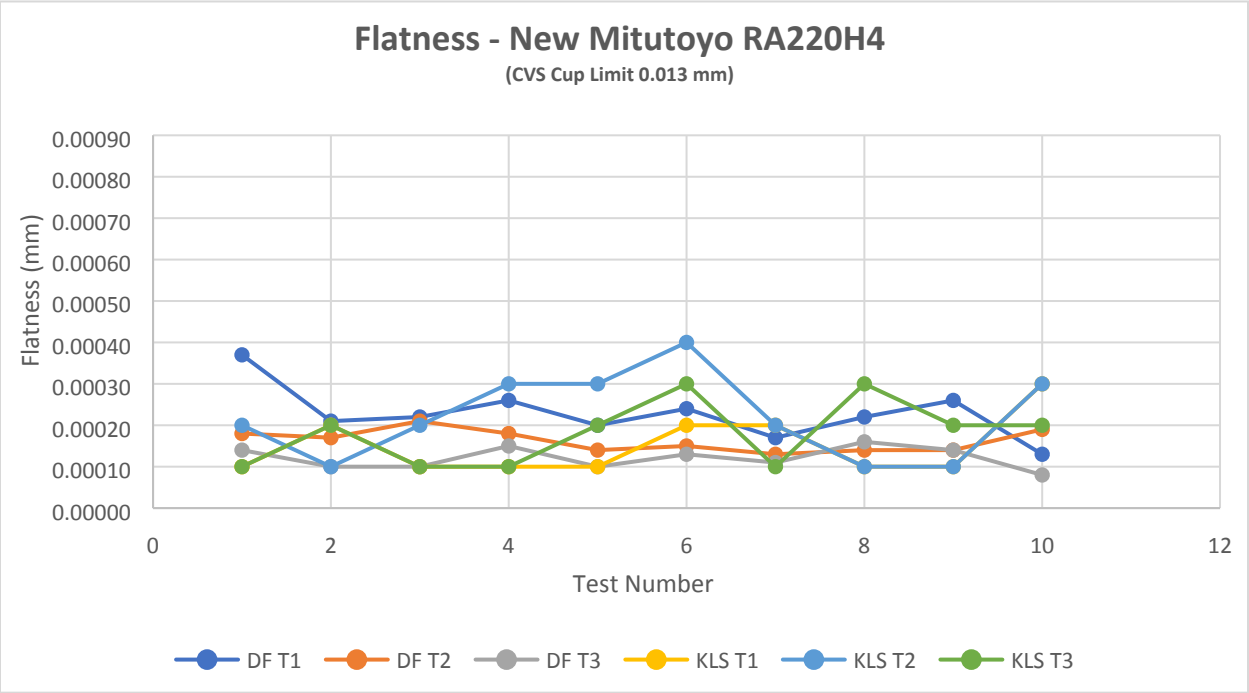

Figure 3. Flatness measurements of Optical Flat A000103 using the Mitutoyo RA-2200 Roundness Machine with 1.5-mm ball. Two inspectors (DF and KLS) completed ten tests each day for three different days (T1, T2, and T3).

Table 2. New Mitutoyo RA-2200 and Predecessor MMQ 400 Optical Flat A000103 Measurements (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.00017	0.00018	0.00020
Standard deviation	0.000061	0.000087	0.000136
RSD (SD/Av) x100	36	48	67
Maximum	0.00037	0.00040	0.00079
Minimum	0.00008	0.00010	0.00003
Range	0.00017	0.00018	0.00020

3. EVALUATION OF CVS REINSPECTION SURVEILLANCE CUPS

Two CVS Reinspection Surveillance cups, 3624-TC25 and 3625-5047, were measured for roundness and flatness per Procedure GPHS-C-3624/25, Rev. 25 (i.e. setup, technique, part position/location). Measurements were made by two inspectors taking ten measurements each day for three days using the Mitutoyo RA-2200. The same stylus with a 1.5-mm ball was used in these inspections as was used when measuring the roundness and flatness standards.

The CVS Reinspection Surveillance cups have been inspected for all features annually (sometimes more often) over the last 17 to 18 years by seven inspectors. The historical Reinspection Surveillance results for roundness and flatness are summarized in Table 3. The table shows that cup 3624-TC25 historically has been found to meet the 0.08-mm and 0.013-mm cup limits for roundness and flatness, respectively. Cup 3625-5047 has been found to meet the cup roundness limit; however, it has never met the cup flatness limit.

Table 3. Historical Formscan 3200 and MMQ 400 Cup Reinspection Results (mm)

	Cup 3624-TC25 – 20 Measurements/18 Years		3625-5047 – 19 Measurements/17 Years	
Statistical Attribute	Roundness Cup Limit 0.08	Flatness Cup Limit 0.013	Roundness Cup Limit 0.08	Flatness Cup Limit 0.013
Average	0.0378	0.0053	0.0433	0.0511
Standard deviation	0.0118	0.0033	0.0073	0.0091
RSD (SD/Av) x 100	31	62	16	17
Maximum	0.0620	0.0104	0.0724	0.0686
Minimum	0.0160	0.0010	0.0316	0.0350
Range	0.0460	0.0094	0.0408	0.0336

4. ROUNDNESS RESULTS FOR REINSPECTION CUPS

The recent roundness evaluation results for cup 3624-TC25 are graphed in Figure 4 and statistically summarized in Table 4 (i.e. averages, standard deviations, relative standard deviations, maximums, minimums, and ranges) while those for cup 3625-5047 are shown in Figure 5 and Table 5. The results indicate that using the Mitutoyo RA-2200 with 1.5-mm-diameter stylus yields results equal to or better than those for the MMQ 400. Comparing the results in Tables 4 and 5 to the appropriate cup roundness results in Table 3 shows, as expected, that the historical reinspection data over many years with seven inspectors has more variation than multiple inspections over 3 days with two inspectors.

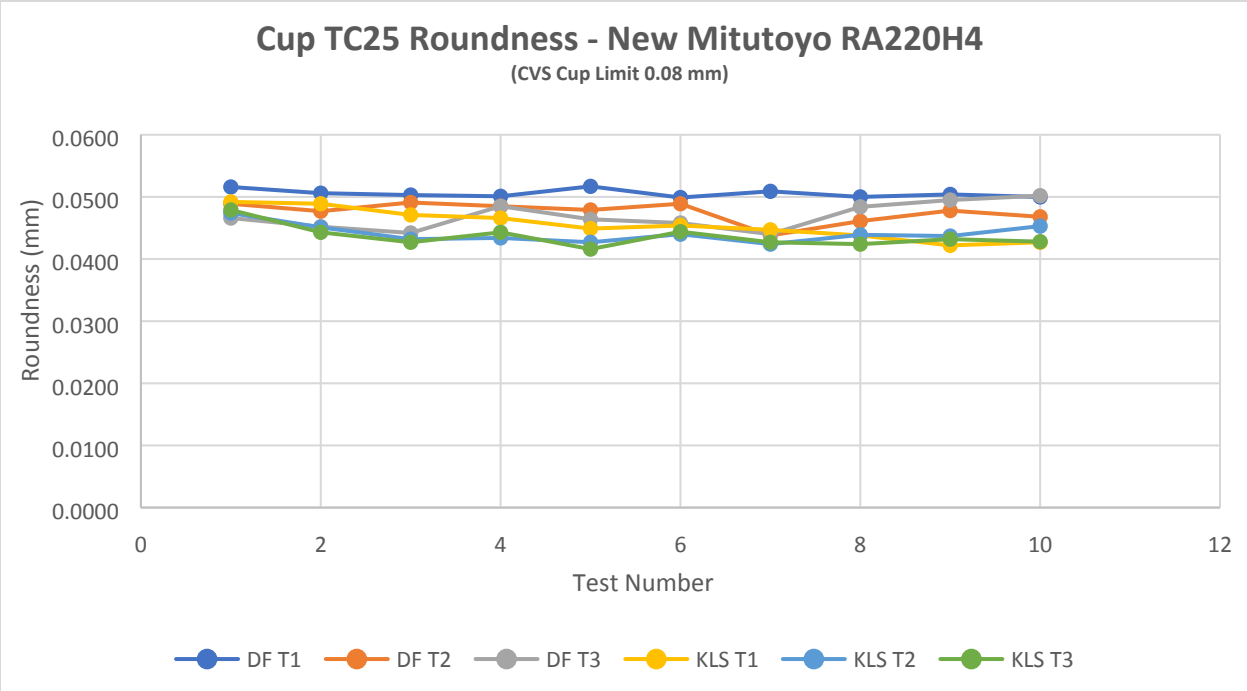

Figure 4. Roundness measurements of CVS Reinspection cup 3624-TC25 using the Mitutoyo RA-2200 with 1.5-mm-diameter styli. Two inspectors (DF and KLS) completed ten tests each day for three different days (T1, T2, and T3).

Table 4. 3624-TC25 Roundness (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.0483	0.0444	0.0438
Std. Dev.	0.0022	0.0020	0.0002
RSD (SD/Av) x 100	5	5	0
Maximum	0.0517	0.0492	0.0440
Minimum	0.0438	0.0416	0.0435
Range	0.0079	0.0076	0.0006

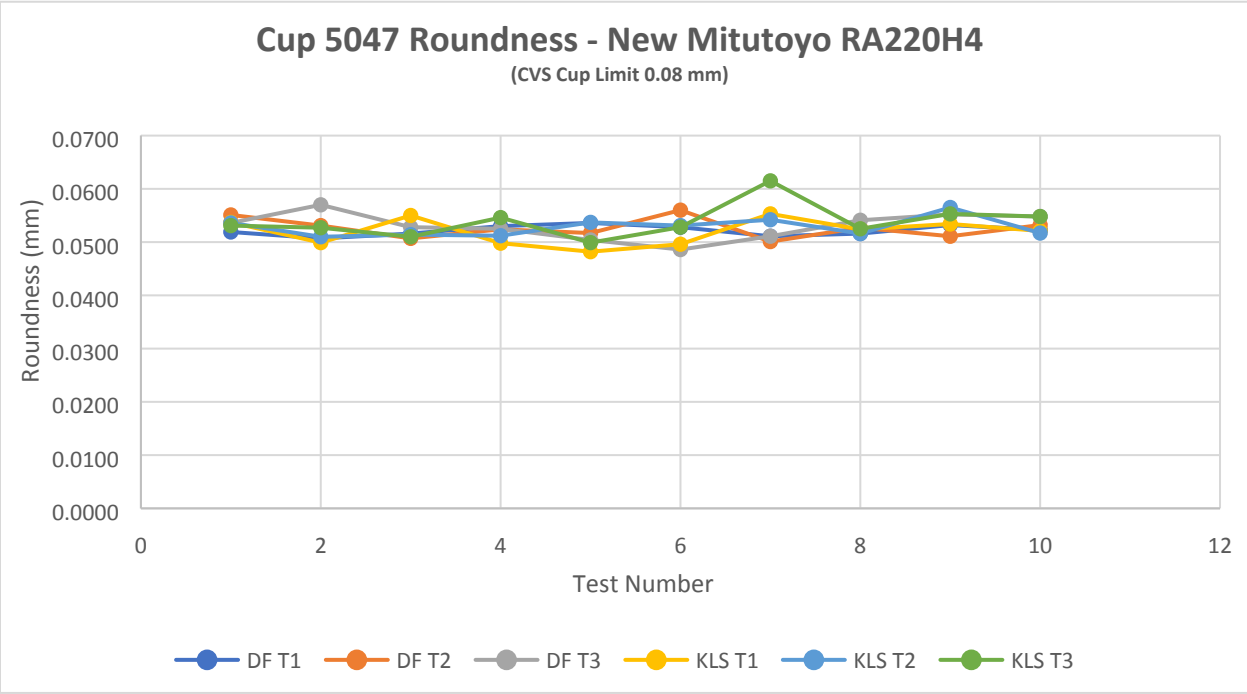

Figure 5. Roundness measurements of CVS Reinspection cup 3625-5047 using the Mitutoyo RA-2200 with 1.5-mm-diameter styli. Two inspectors completed ten tests each day for three different days.

Table 5. 3625-5047 Roundness (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.0526	0.0529	0.0389
Std. Dev.	0.0018	0.0026	0.0041
RSD (SD/Av) x 100	4	5	11
Maximum	0.0570	0.0615	0.0447
Minimum	0.0486	0.0482	0.0359
Range	0.0084	0.0133	0.0088

5. FLATNESS RESULTS FOR REINSPECTION CUPS

The recent flatness evaluation results for cup 3624-TC25 are graphed in Figure 6 and statistically summarized in Table 6 (i.e. averages, standard deviations, relative standard deviations, maximums, minimums, and ranges) while those for the out-of-flat cup 3625-5047 are shown in Figure 7 and Table 7. Again, the results indicate that using the Mitutoyo RA-2200 with the 1.5-mm-diameter stylus yields results equivalent to or better than those for the MMQ 400. Comparing the results in Tables 6 and 7 to the appropriate cup flatness results in Table 3 shows, as expected, that the historical reinspection data over many years with seven inspectors has more variation than multiple inspections over 3 days with two inspectors.

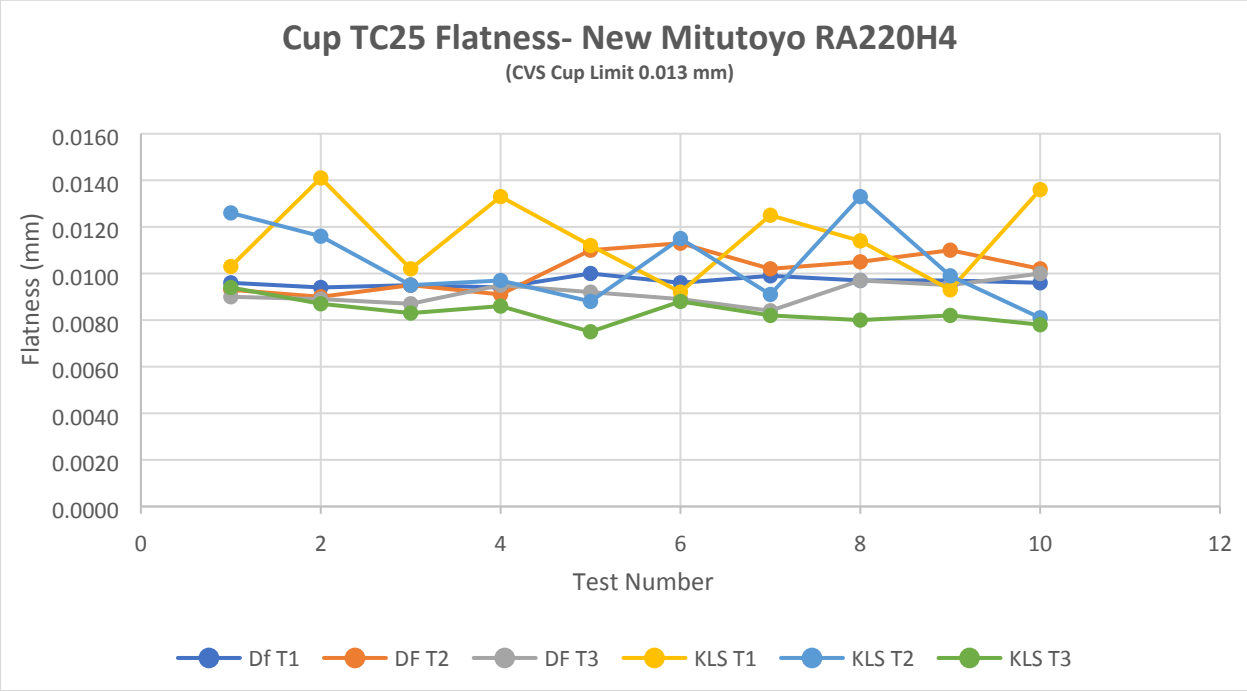

Figure 6. Flatness measurements of CVS Reinspection cup 3624-TC25 using the Mitutoyo RA-2200 with 1.5-mm-diameter styli. Two inspectors (DF and KLS) completed ten tests each day for three different days (T1, T2, and T3).

Table 6. 3624-TC25 Flatness (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.0096	0.0101	0.0085
Std. Dev.	0.0007	0.0019	0.0008
RSD (SD/Av) x 100	7	19	10
Maximum	0.0113	0.0141	0.0105
Minimum	0.0084	0.0075	0.0075
Range	0.0029	0.0066	0.0030

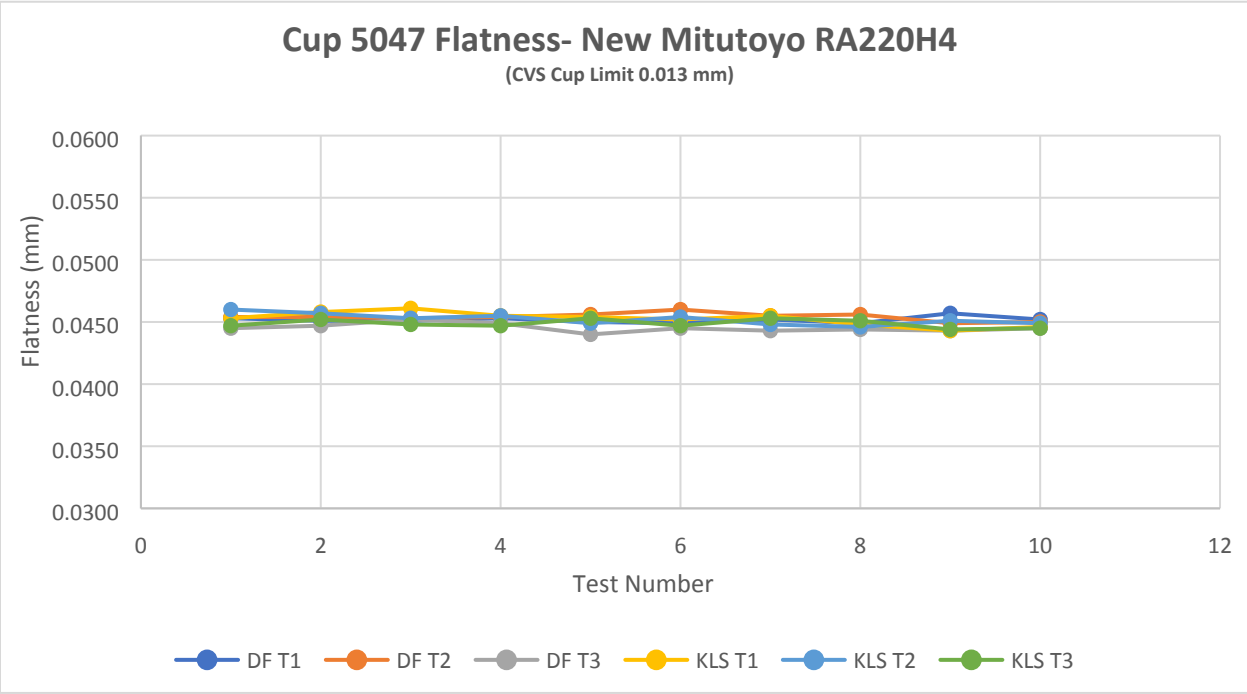

Figure 7. Flatness measurements of CVS Reinspection cup 3625-5047 using the Mitutoyo RA-2200 with 1.5-mm-diameter styli. Two inspectors (DF and KLS) completed ten tests each day for three different days (T1, T2, and T3).

Table 7. 3625-5047 Flatness (mm)

Statistical Attribute	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector DF	Mitutoyo RA-2200 1.5-mm-diam stylus Inspector KLS	MMQ 400 2-mm-diam stylus (Ulrich, Walls, & Wright, 2009)
Average	0.0450	0.0451	0.0542
Std. Dev.	0.0005	0.0005	0.0017
RSD (SD/Av) x 100	1	1	3
Maximum	0.0460	0.0461	0.0570
Minimum	0.0440	0.0443	0.0520
Range	0.0020	0.0018	0.0050

6. SUMMARY

These evaluations have shown that the new Mitutoyo RA-2200 yields CVS cup roundness and flatness inspection results that are equivalent to or better than the predecessor MarForm MMQ 400 Formtester machine.

The new Mitutoyo RA-2200 is considered qualified for CVS cup dimensional inspection work per procedure GPHS-C-3624/25, Rev. 25. A Radioisotope Power Systems Special Component manufacturing and Testing Program deviation request will be submitted to modify the inspection procedure.

References

1) Ulrich, G. B., Walls, B. D., & Wright, W. E., *Qualification of Mahr Federal MarForm MMQ 400 Form Measuring Instrument for Clad Vent Set Cup Roundness and Flatness Inspections*, attachment to ORNL Letter No. 1014-27-09, J.F. King to J. Dowicki, October 14, 2009.