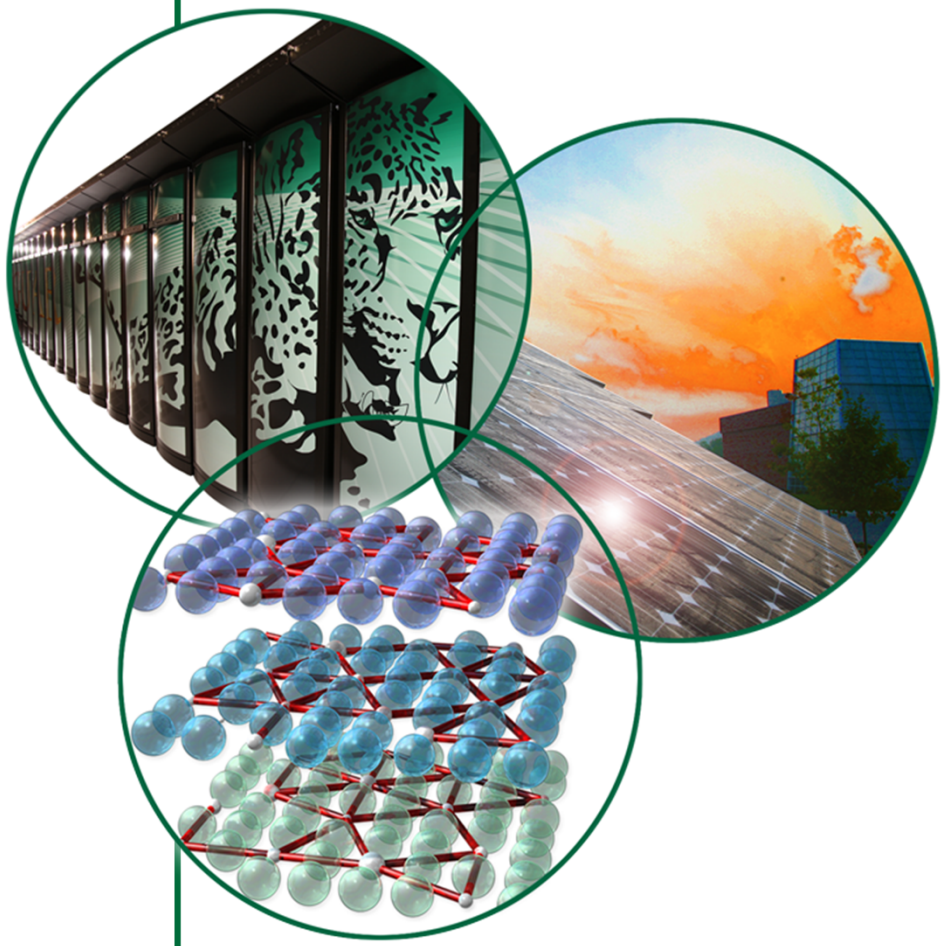
MERIT Primary Containment Chamber Surface Inspection – Updated Dec 5, 2011

V. Graves



MERIT EVO

November 23, 2011

U.S. DEPARTMENT OF ENERGY

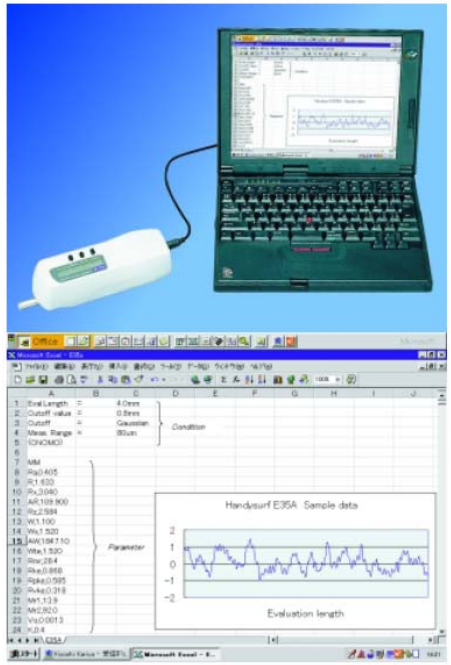
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

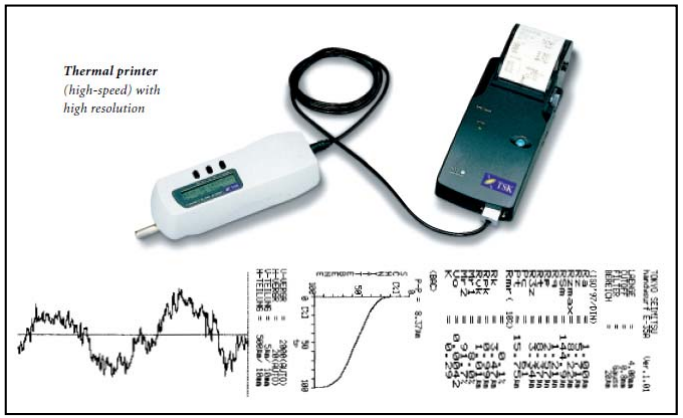
Surface Profilometer Measurements of MERIT Primary Containment Chamber

- Concern that high-velocity mercury beads generated during MERIT experiment might have induced pitting on the interior surface of mercury jet chamber
- Photography of the surfaces in Sept 2010 revealed no observable surface issues
- Desired to have a quantitative measurement of the surface profile around the viewports

Zeiss HandySurf E-35

- Portable, hand-held surface tester for measuring roughness and contour
- Output
  - Read-out unit provides calculated values
  - Printer
  - Data points to Excel





Handysurf Specifications

- Traversing length: 12.5mm
- Tracing speed: 0.6mm/s
- Evaluation length: 0.4 – 12.5mm with 0.1mm step
  0.4/1.25/4/12.5mm
- Measuring range: 40/160**µm**
- Resolution: 0.02**µm**
- Stylus radius: 5**µm**
- Skid: Sapphire, radius 40mm

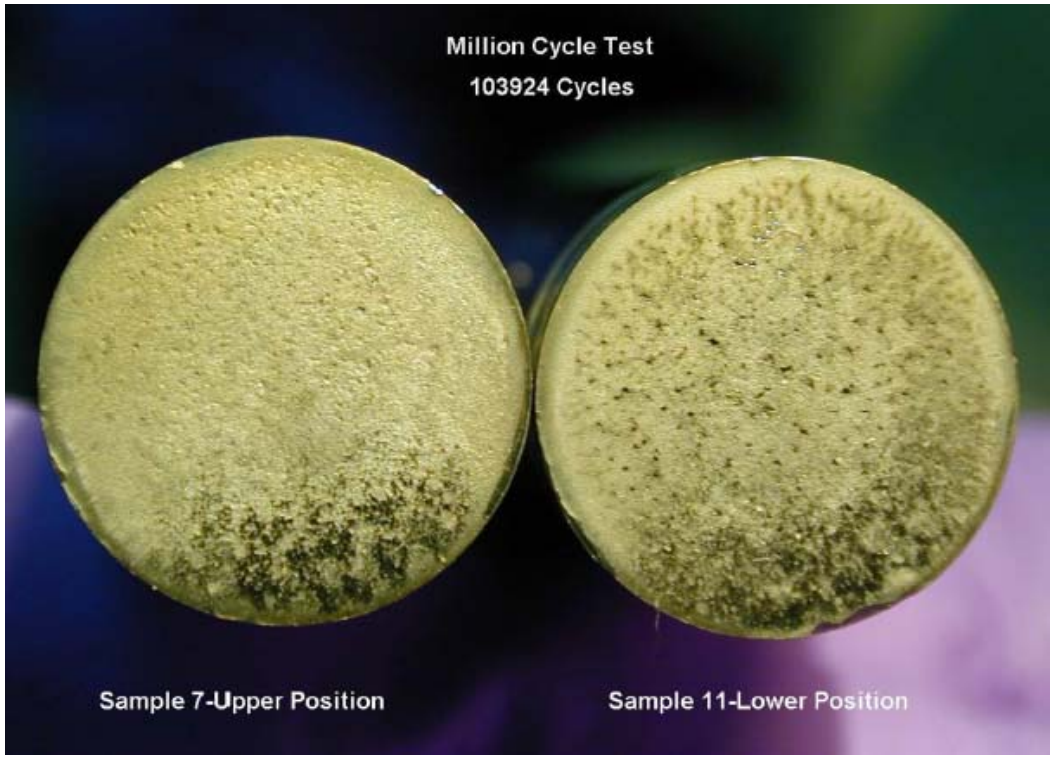
Surface Finish Applications Guide

- Various statistical parameters that Surface Profilometers support
- Various international standards define these parameters
- We're really interested only in the raw profile data

Function	Description	Relevant workpiece	Evaluation Parameter
Sealing Tightness	Leakage from gap between contact surfaces	Valve, Cock, Cylinder	Ra, Rp, Sm, Rpk
Abrasion resistance	Force to be caught by roughness peak	Clutch, Knock pin	Δa ,Δq, Ry, Rz, Rp
Abrasion	Loads concentrated on a convex upon sliding	Shaft, Bearing Cylinder hole, Piston ring, Guide surface	Rp, Bearing length ratio curve, tp, Rpk, Rsk
Burning, Lubricating ability	Deposit lubricating oil in valleys	Plateau honing surface of cylinder block bore	Rv, Bearing length ratio curve,tp, Rvk, Rδc, Hp, Mr2, Vo, K
Adhesion	Wringing Optimum	Blockgauge PC Board	Flatness, Ry, Rmax
Bonding	Form for bonding agent, Uneasiness to peel off	Bonding surface, Plating foundation	Rz, Ry, Δa, Δq, Lr
Peel ability	Ability to remove molding from mold	Die	Rz,Ry,Δa,Δq,Lr
Appearance, Gloss	Scattering in reflection of light, Glaring, High quality feeling	Plating surface Rainbow surface Pattern finish Mirror surface	Δq, Rq, Ra, W_{CM}, W_{CA}, Power graph, Rku, Rpk
	Glossy surface (Brightness of coated surface)	Cold-rolled steel for car	W_{CA}, Ra, Pc, PPI
Optical performance	Turbulence of beam reflection, Scattering	Mirror, Lens, Prism	Δq, Rq, Ra
Corrosion resistance, Insulation ability	Easiness to be wet due to capability	Weatherproof parts, Electric parts	Ra, Δa, Δq, Rv, Mr2
Fatigue strength	Concentration of stress due to the form of notch	Crank shaft	Rmax, Rv, Rvk
Electromagnetic characteristic	Disturbance of skin effect by flows and roughness	Waveguide, Magnetic core	Ra, Ry, Rz
Electric resistance of contact surface, Heat resistance	Electric resistance due to contact surface, heat transfer	Relay, Switch Connector, Radiator	tp, Mrl, Ra, Lr
Rigidity of junction surface	Deflection due to excessively small conjunction surface	Bolt clamping portion	Parallelism, W_{EM}, tp, Rz, Rp, Rpk
Accuracy of dimensional measurement	Measurement error due to roughness, deformation of roughness due to meas. pressure	Micrometer, Air micrometer Calipers	Parallelism, Ry, Rp, Rpk
Texture	The touch	Knurling tool, Satin surface	Rp, Δa, Δq, Sm, Pc, Power graph
Printing quality	Fitting of ink and paper	Printing paper	Ra, Rv, Rvk, Sm, Pc, Power graph
Noise, Vibration	Vibration of rolling surface at high speed	Gear, Roller bearing, Guide surface	Rp, Rmax, W_{EM}, Sm, Power graph

Split-Hopkinson Pressure Bar used for SNS Hg Target Pitting Simulation Studies

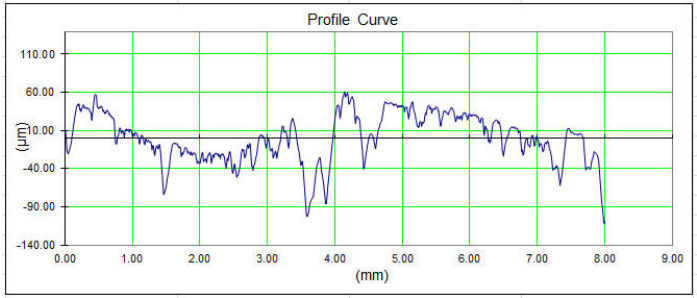
- Process automated for high test cycles
- 1 Hz repetition rate

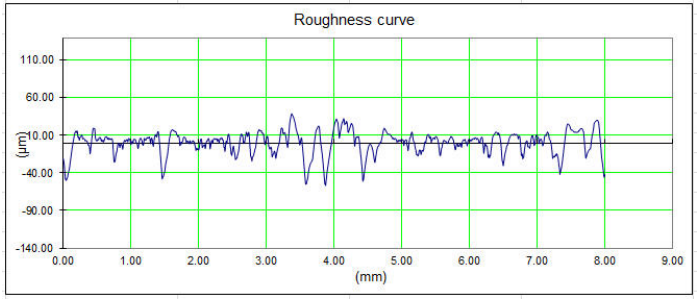


Some Control Measurements

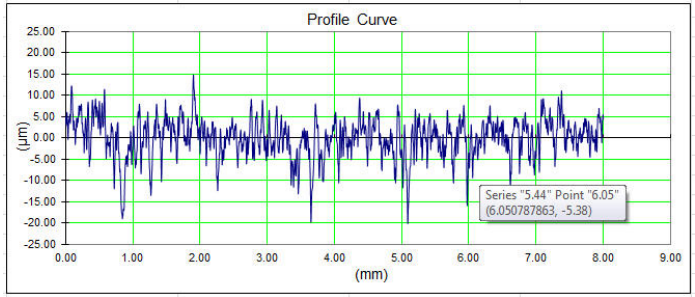
- Specimens had known surface finishes prior to experiment
- Specimens have varying degrees of surface damage

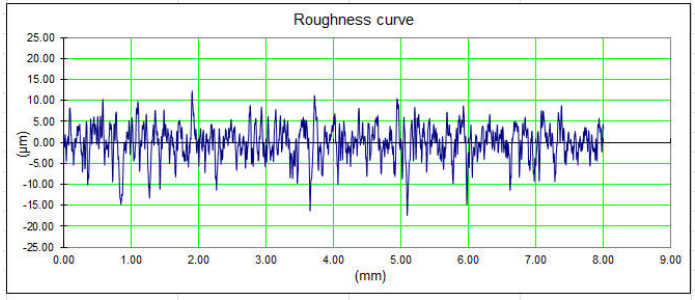
Comparative Results – Different Scales





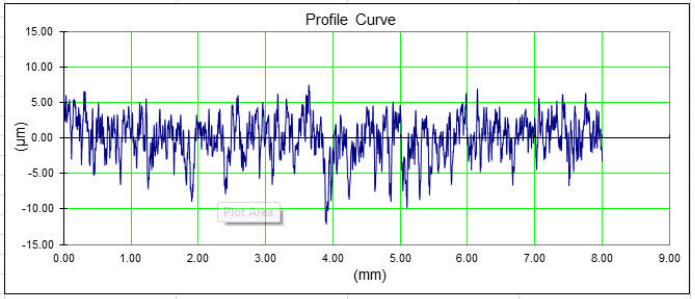
Specimen 11

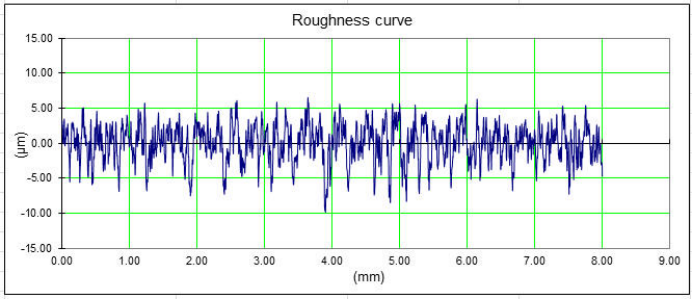




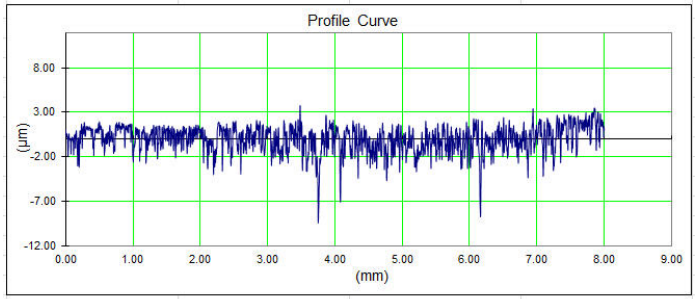
Specimen 13

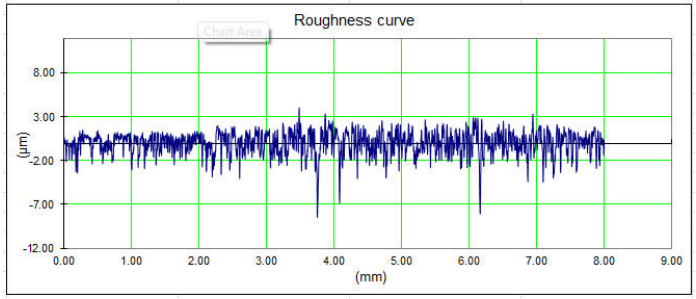
Approximately 7500 pts / 8mm sample length





Specimen 14



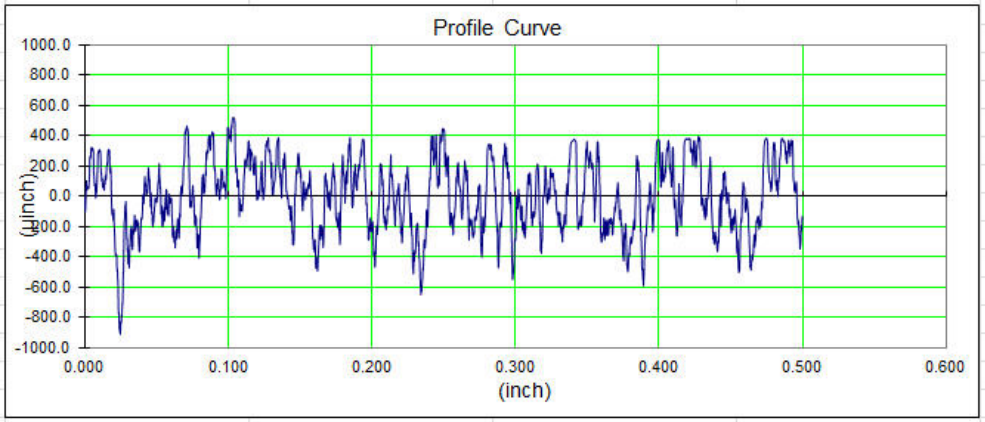


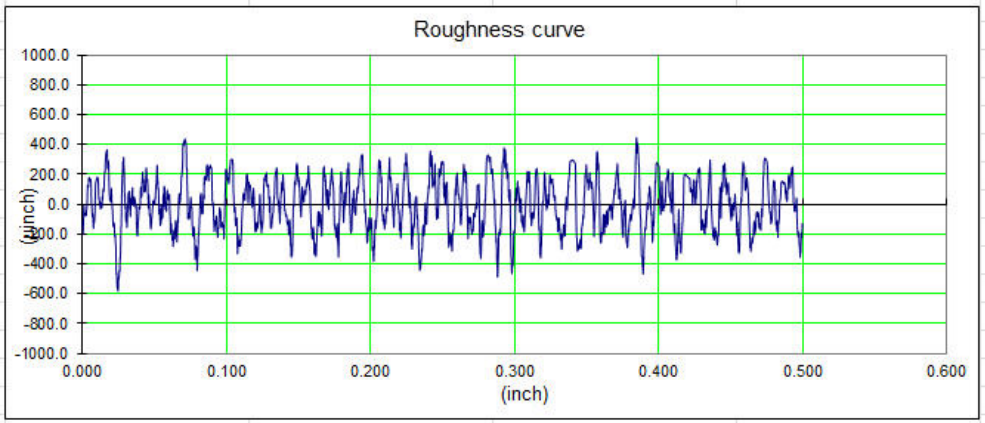
Specimen 18

What distinguishes a pit from other surface irregularities?

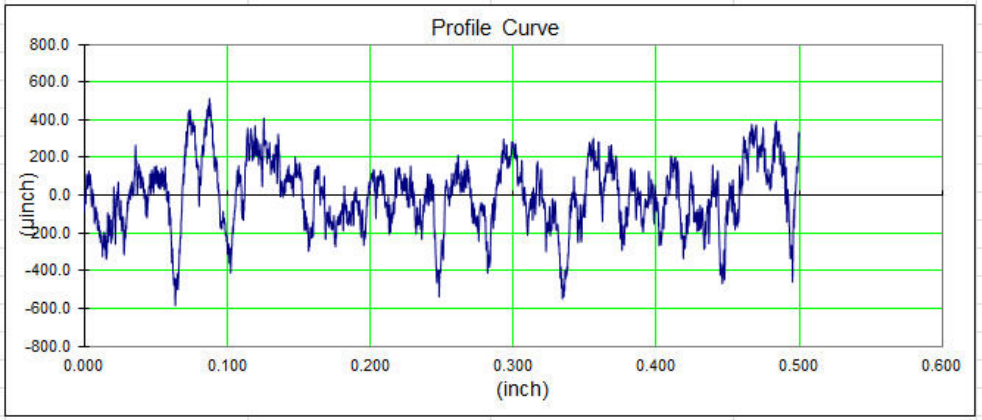
Additional Comparative Testing – Stainless Steel Specimens

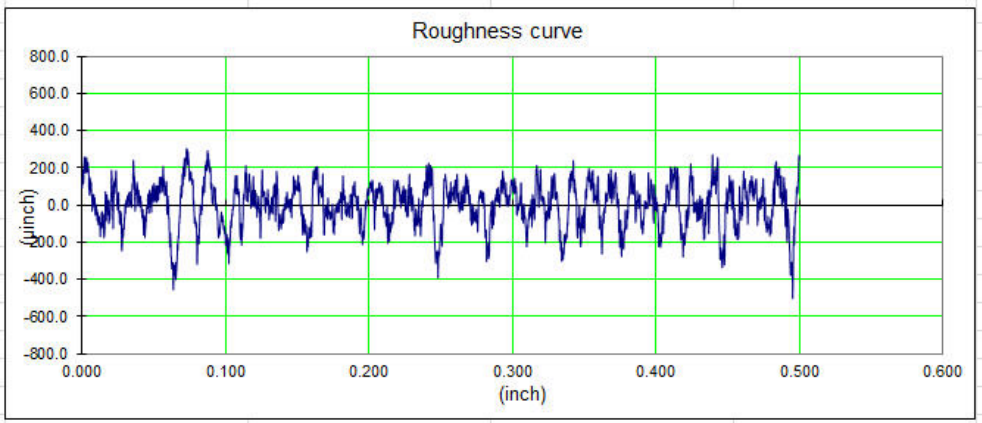
- Raw stock and sandblasted specimens measured with Handysurf





Raw Stock

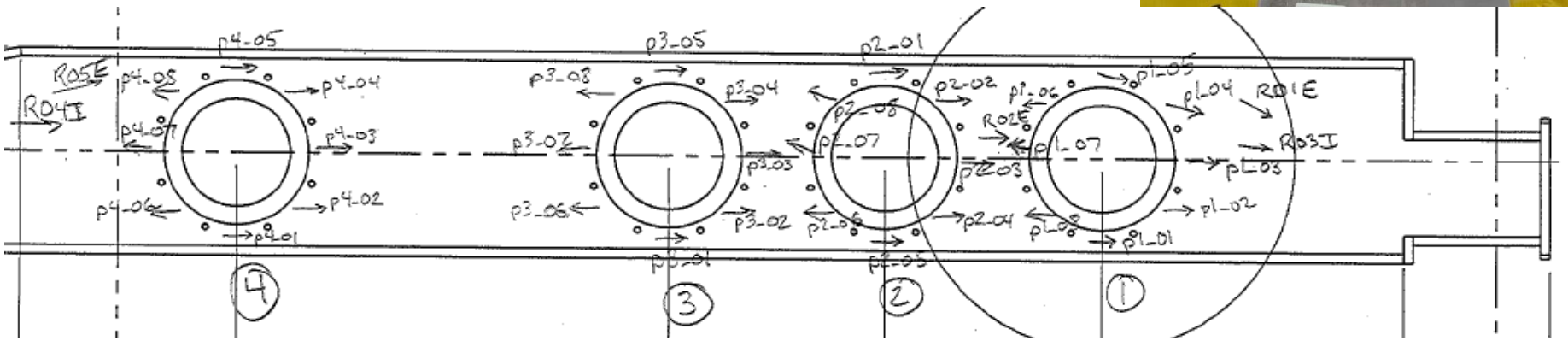




Sandblasted Stock

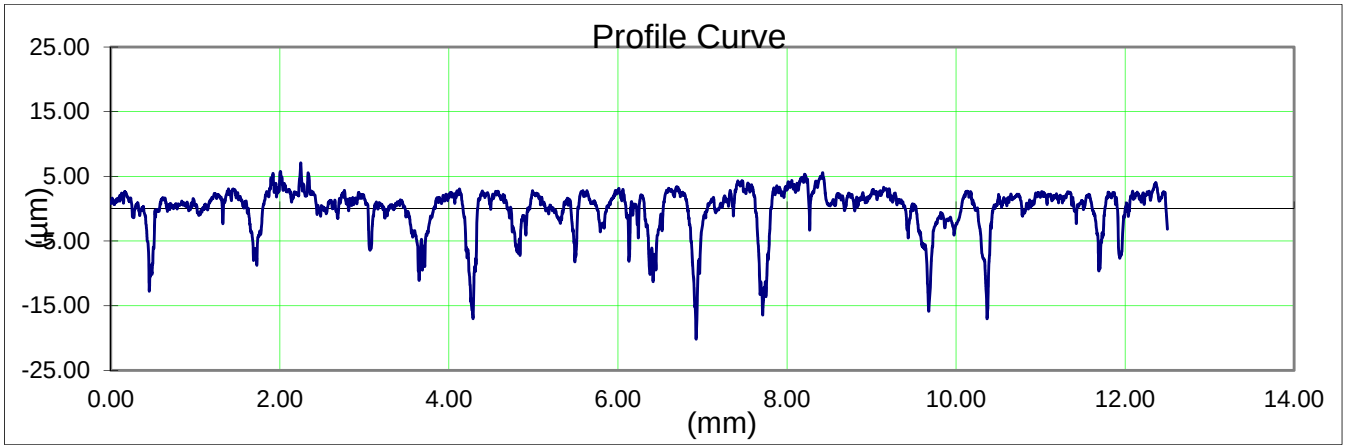
Scans Performed On/In MERIT Chamber

- Scans obtained around 4 viewports on right side as seen by beam
  - A few scans on exterior for comparison
- All scans 12.5mm in length (maximum)



Some Exterior Scans on Chamber – A Machined Surface

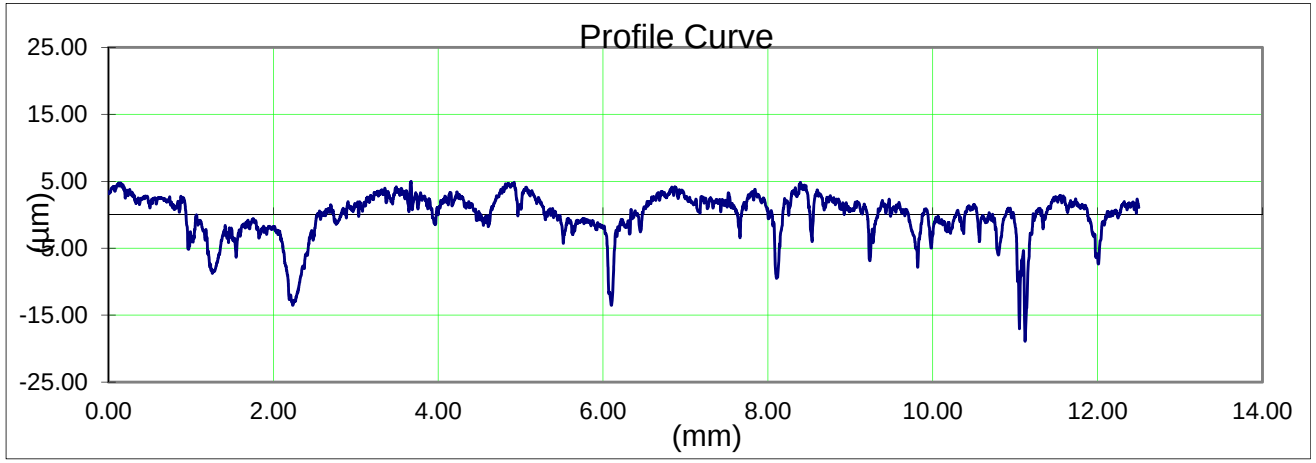
R01



Ra	1.83	Rmr	6.5
Rmax	20.92	Rk	3.24
Rz	12.74	Rpk	0.81
RSm	320.20	Rvk	7.45
Rq	2.54	Mr1	8.3
Rpm	3.42	Mr2	78.7
Rp	4.62	Vo	0.0793
Rt	21.68	K	2.3
Pc	101		

Note the peaks of these scans are relatively flat from machining, while the valleys are deep

R02



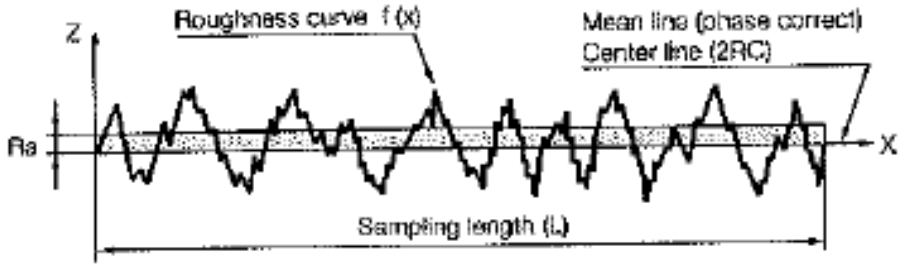
Ra	1.20	Rmr	18.6
Rmax	18.98	Rk	2.22
Rz	7.77	Rpk	0.72
RSm	262.50	Rvk	4.75
Rq	1.65	Mr1	8.1
Rpm	2.36	Mr2	78.4
Rp	4.48	Vo	0.0513
Rt	18.98	K	2.14
Pc	139		

Arithmetic Mean Deviation of Profile

Arithmetic mean deviation of profile (Ra) :
This is the value obtained by the following formula when the sampling length (or evaluation length in JIS '82), L from the roughness curve, taking X-axis in the direction of the mean line and Z-axis in the direction of the longitudinal magnification of this sampled curve is expressed by Z = f (x). After having calculated the value in each reference length, the average value in the whole evaluation length is output. (In JIS '82, the value which has been calculated in the whole evaluation length is output.)

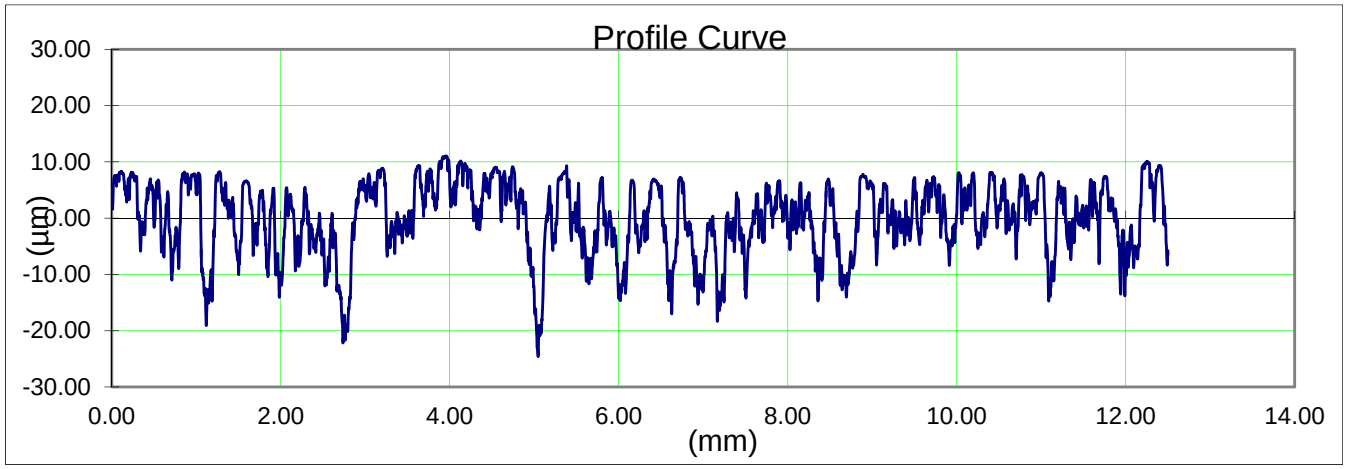
$$Ra = \frac{1}{L}\int_0^L \left| f(x) \right| dx$$

Namely, in the figure below, the arithmetic average represents the average deflection obtained by dividing the area of the portion surrounded by the roughness curve and the mean line by the measuring sampling length.



Some Random Interior Scans – A Raw Stock Surface

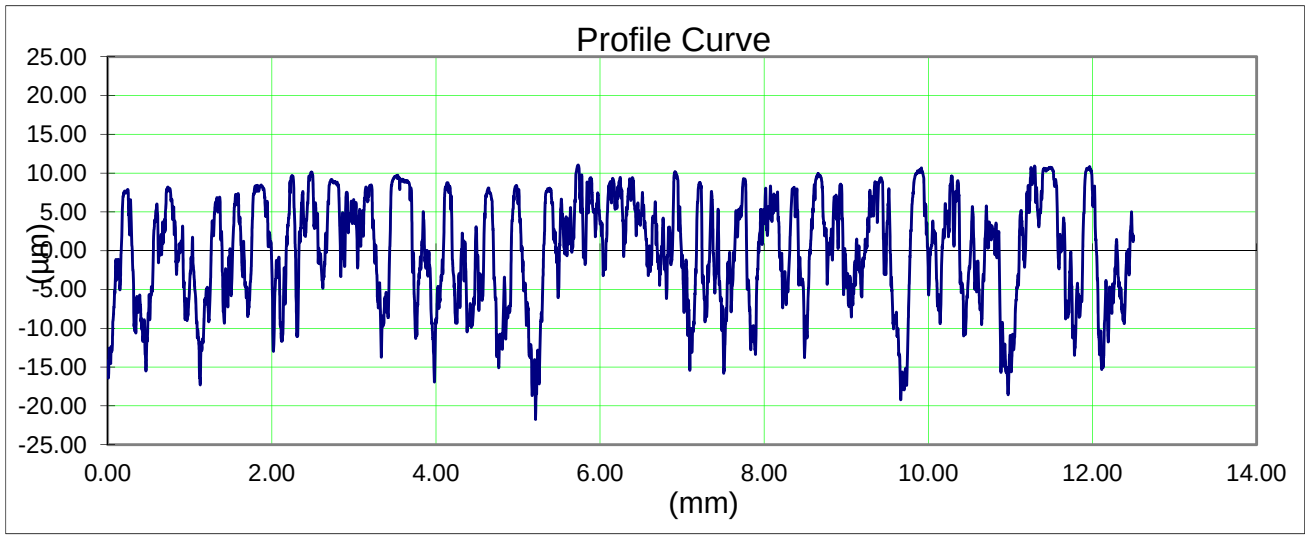
R03



Ra	4.10	Rmr	4.6
Rmax	28.90	Rk	13.32
Rz	20.22	Rpk	1.85
RSm	227.20	Rvk	7.14
Rq	4.87	Mr1	3
Rpm	8.00	Mr2	85.8
Rp	10.44	Vo	0.0507
Rt	28.90	K	0.54
Pc	135		

Both the peaks and valleys of these scans are relatively jagged

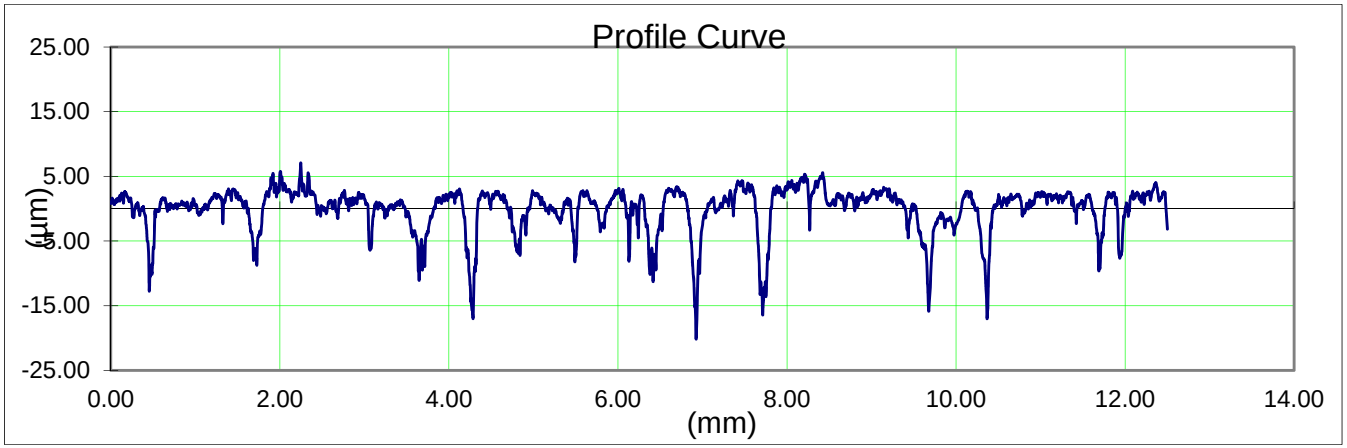
R04



Ra	4.77	Rmr	7.1
Rmax	28.42	Rk	17.59
Rz	22.53	Rpk	1.72
RSm	246.60	Rvk	5.44
Rq	5.68	Mr1	3.7
Rpm	9.43	Mr2	89.3
Rp	12.16	Vo	0.029
Rt	28.64	K	0.31
Pc	117		

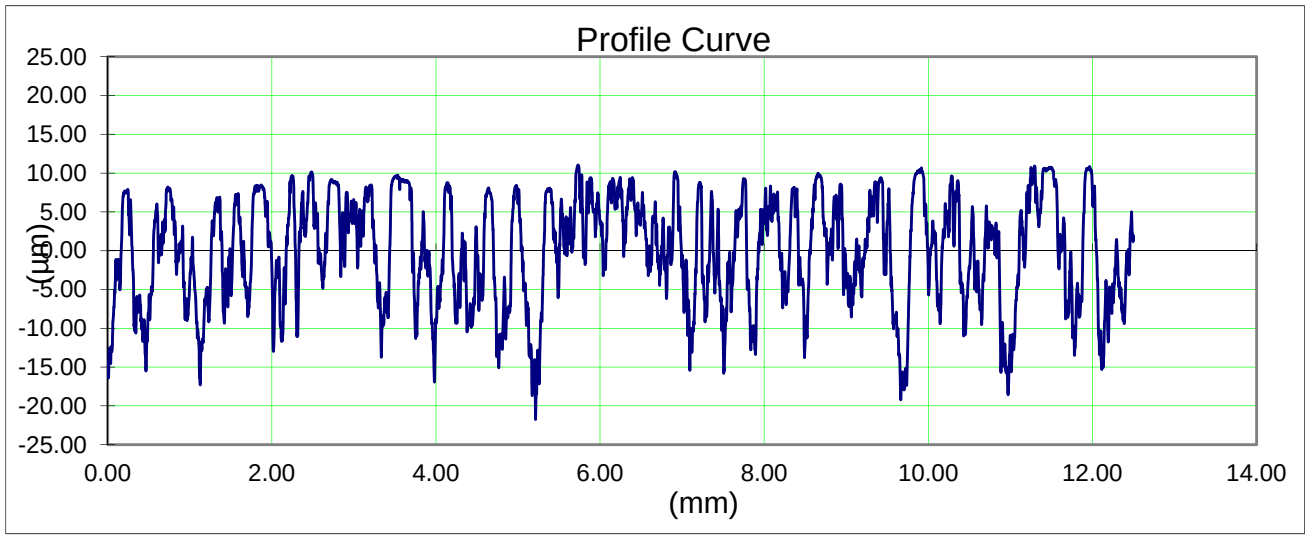
Interior/Exterior Comparison

R01 (Exterior Scan)



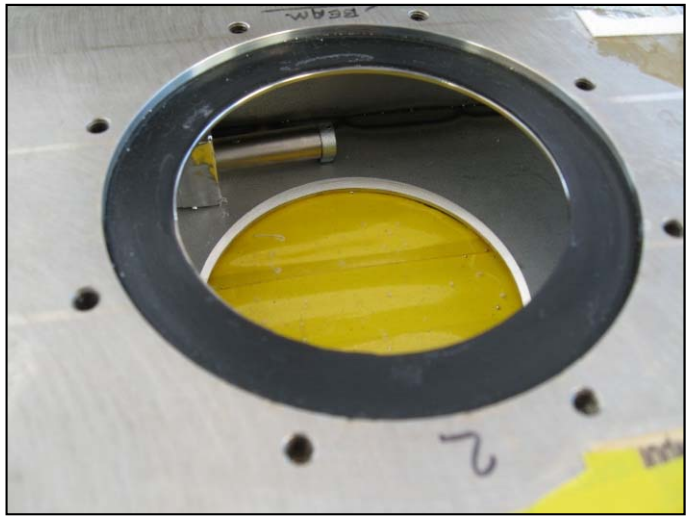
Ra	1.83	Rmr	6.5
Rmax	20.92	Rk	3.24
Rz	12.74	Rpk	0.81
RSm	320.20	Rvk	7.45
Rq	2.54	Mr1	8.3
Rpm	3.42	Mr2	78.7
Rp	4.62	Vo	0.0793
Rt	21.68	K	2.3
Pc	101		

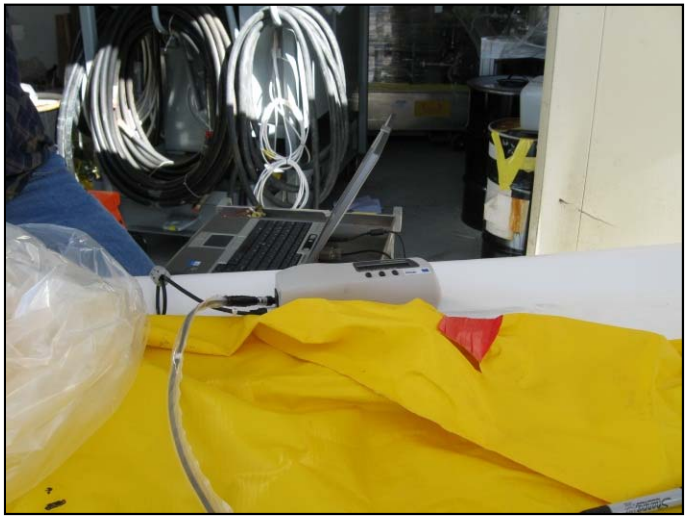
R04 – Interior Scan

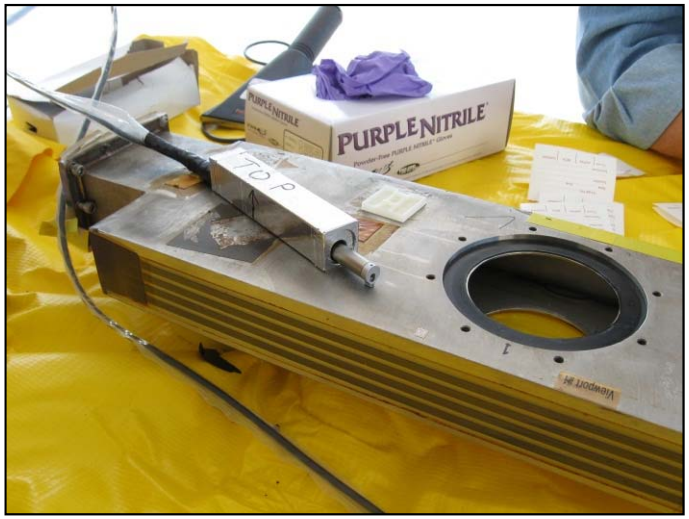


Ra	4.77	Rmr	7.1
Rmax	28.42	Rk	17.59
Rz	22.53	Rpk	1.72
RSm	246.60	Rvk	5.44
Rq	5.68	Mr1	3.7
Rpm	9.43	Mr2	89.3
Rp	12.16	Vo	0.029
Rt	28.64	K	0.31
Pc	117		

Measurement Photos

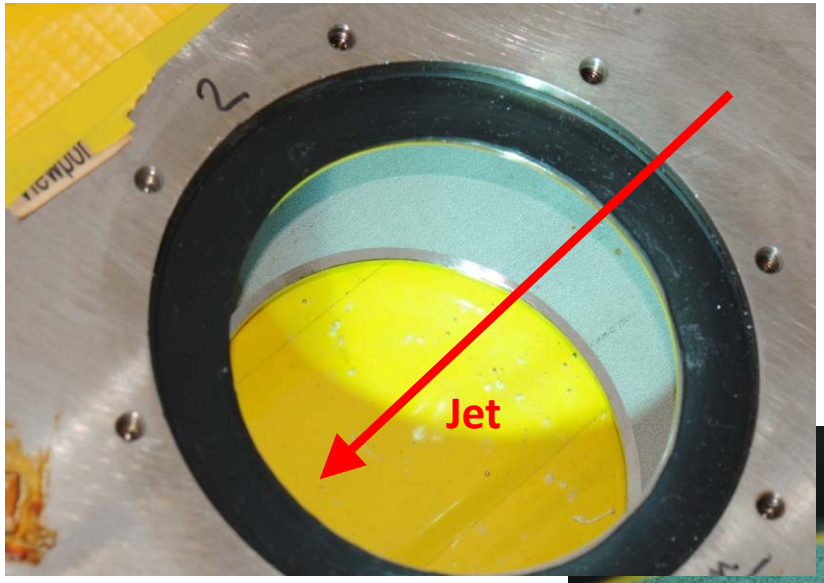


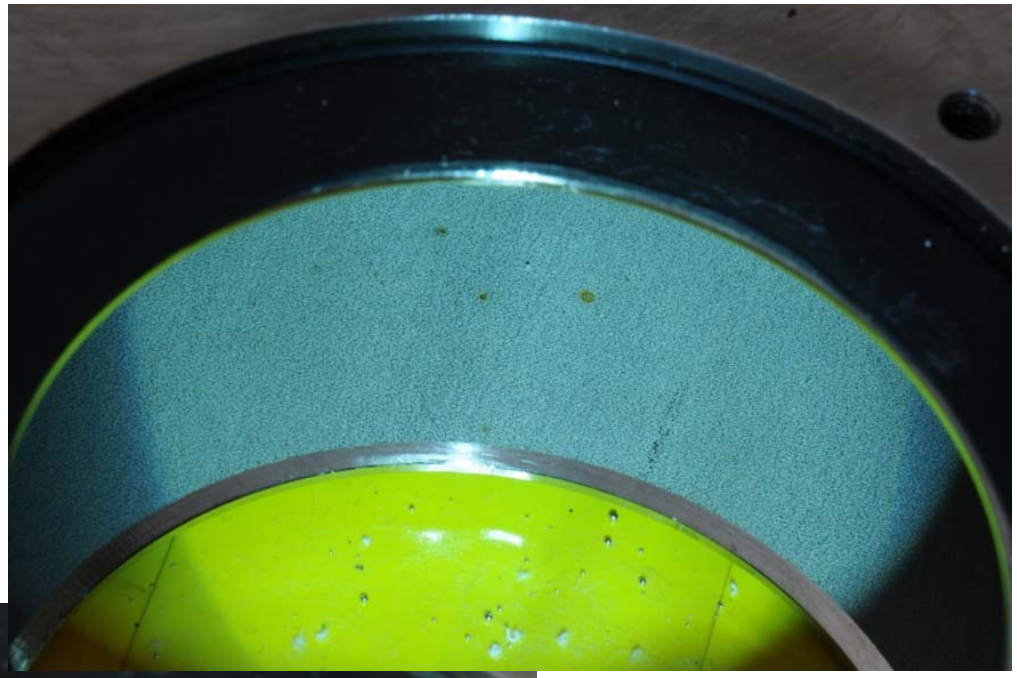


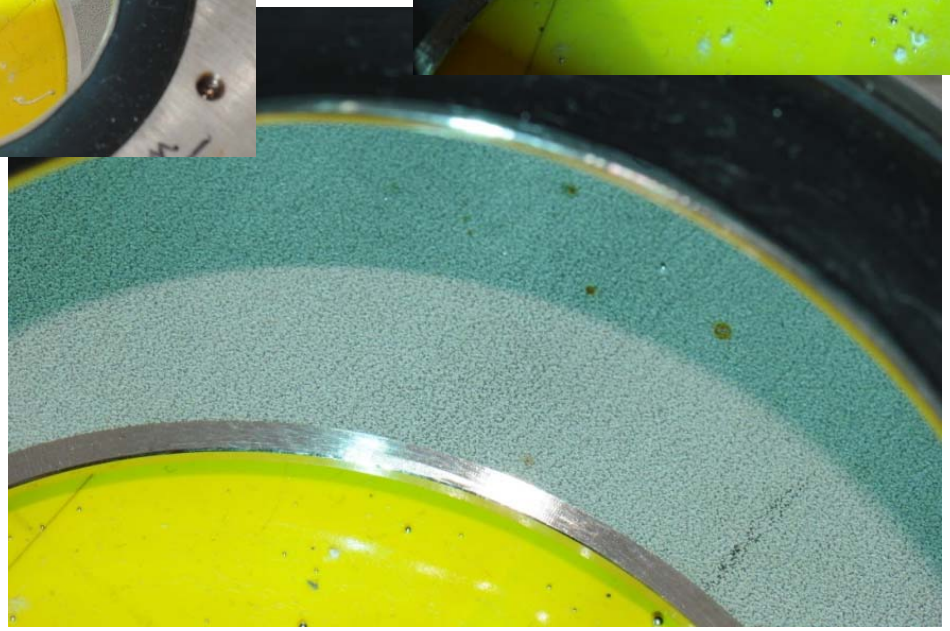


Viewport 2 Upstream Side Photos Taken Sept 2010

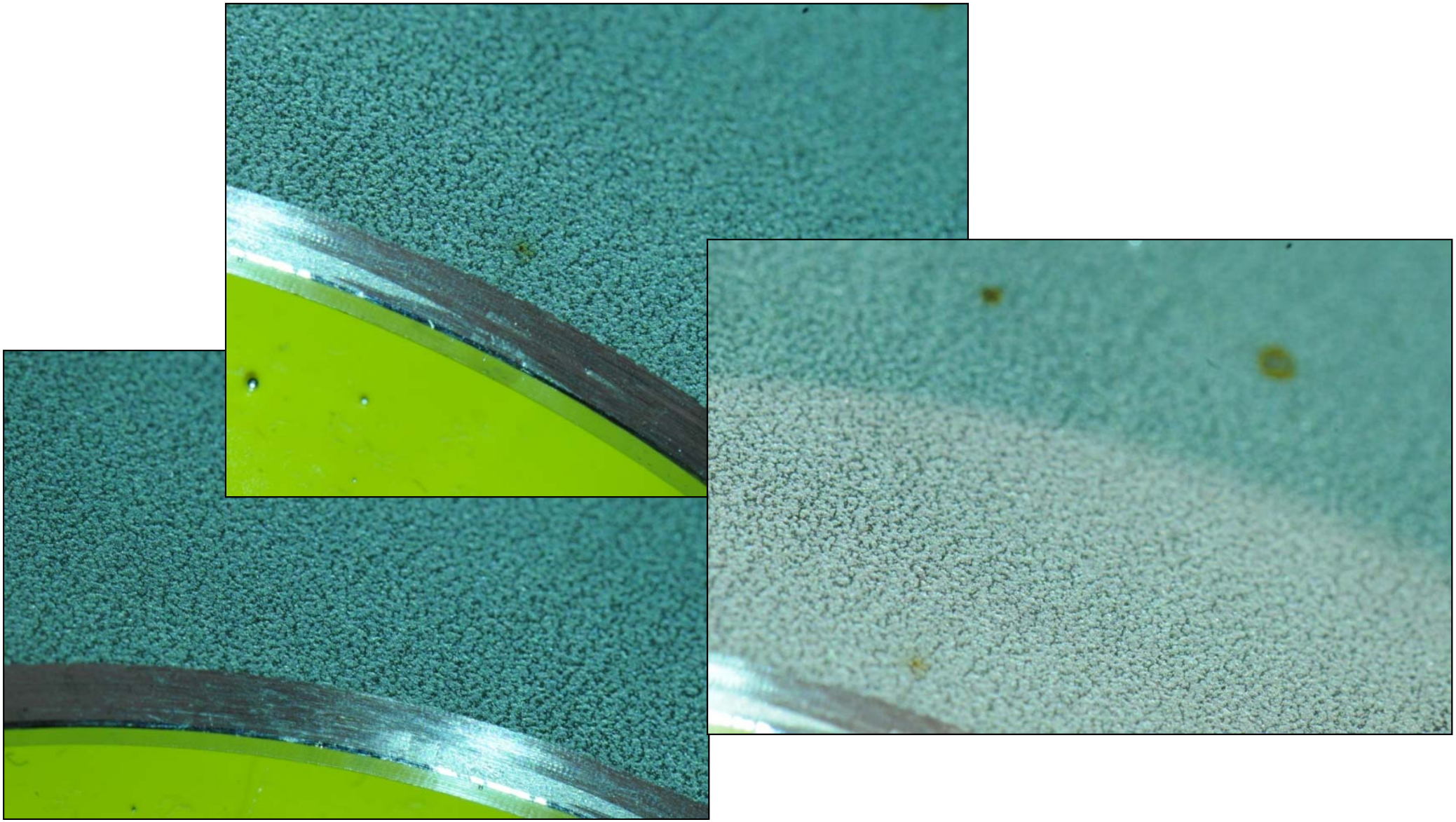
- General surface appearance is uniform







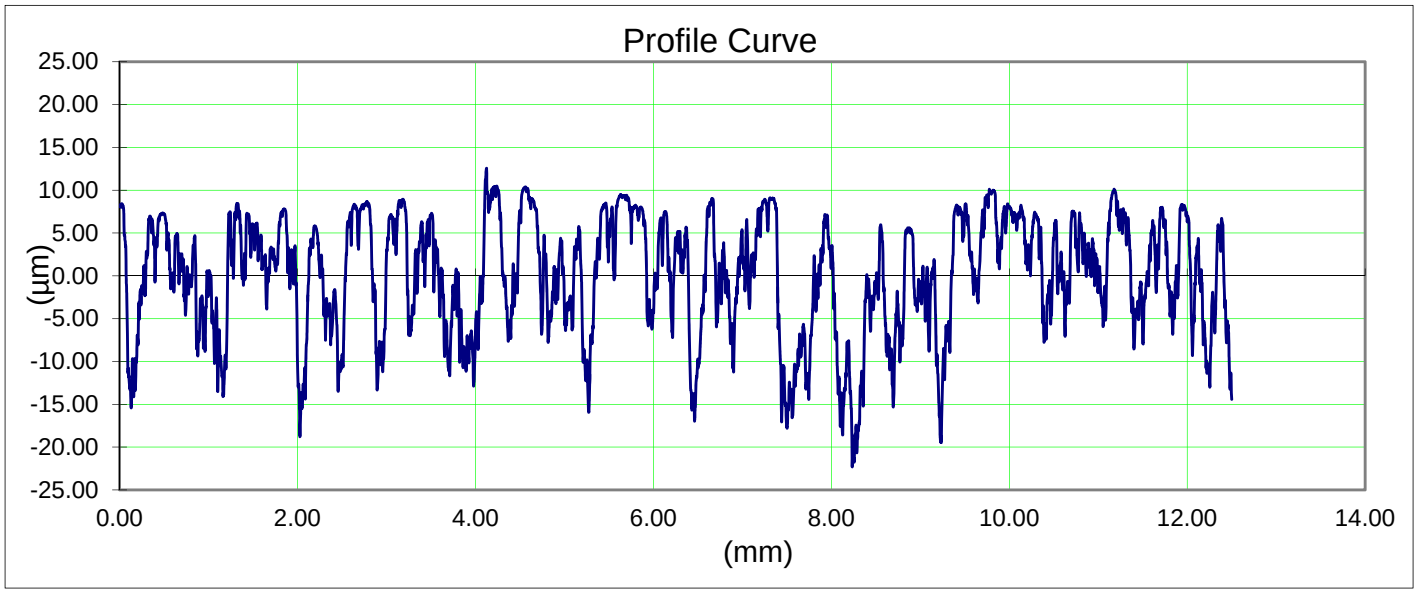
Viewport 2 Upstream Side Close-Ups



- Complete presentation
  http://www.hep.princeton.edu/~mcdonald/mumu/target/graves/graves_101310.pdf

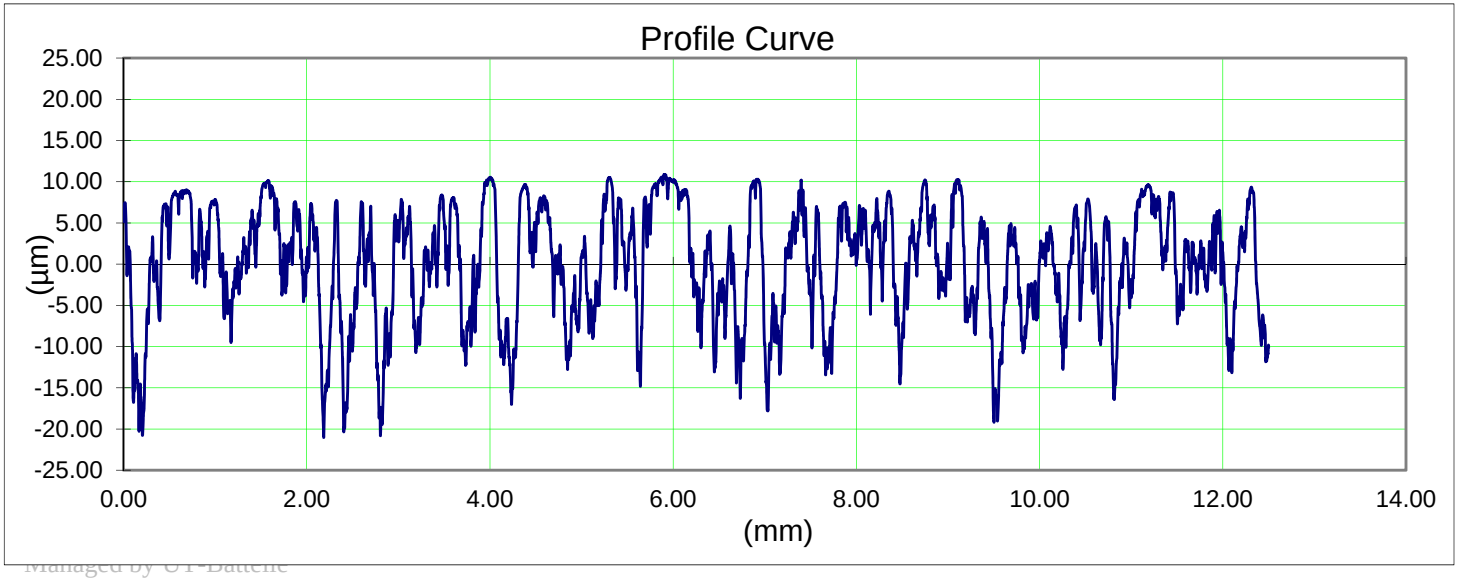
Viewport 2 Scans 1-2

P2_01



Ra	4.31	Rmr	2
Rmax	25.02	Rk	13.12
Rz	21.37	Rpk	2.34
RSm	266.30	Rvk	7.04
Rq	5.17	Mr1	3.7
Rpm	8.68	Mr2	82.5
Rp	11.08	Vo	0.0617
Rt	27.84	K	0.54
Pc	108		

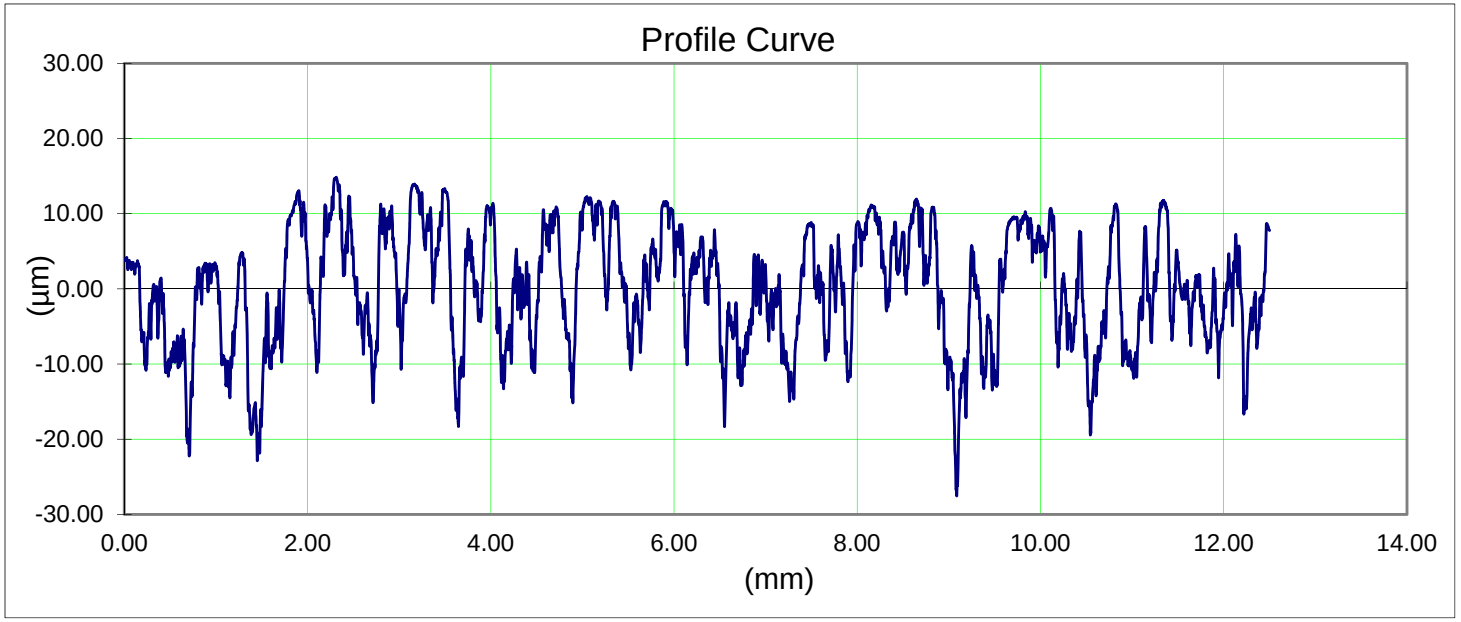
P2_02



Ra	4.59	Rmr	1.9
Rmax	30.62	Rk	14.28
Rz	23.03	Rpk	2.61
RSm	231.50	Rvk	7.4
Rq	5.51	Mr1	4.2
Rpm	9.41	Mr2	83.1
Rp	14.16	Vo	0.0625
Rt	31.58	K	0.52
Pc	108		

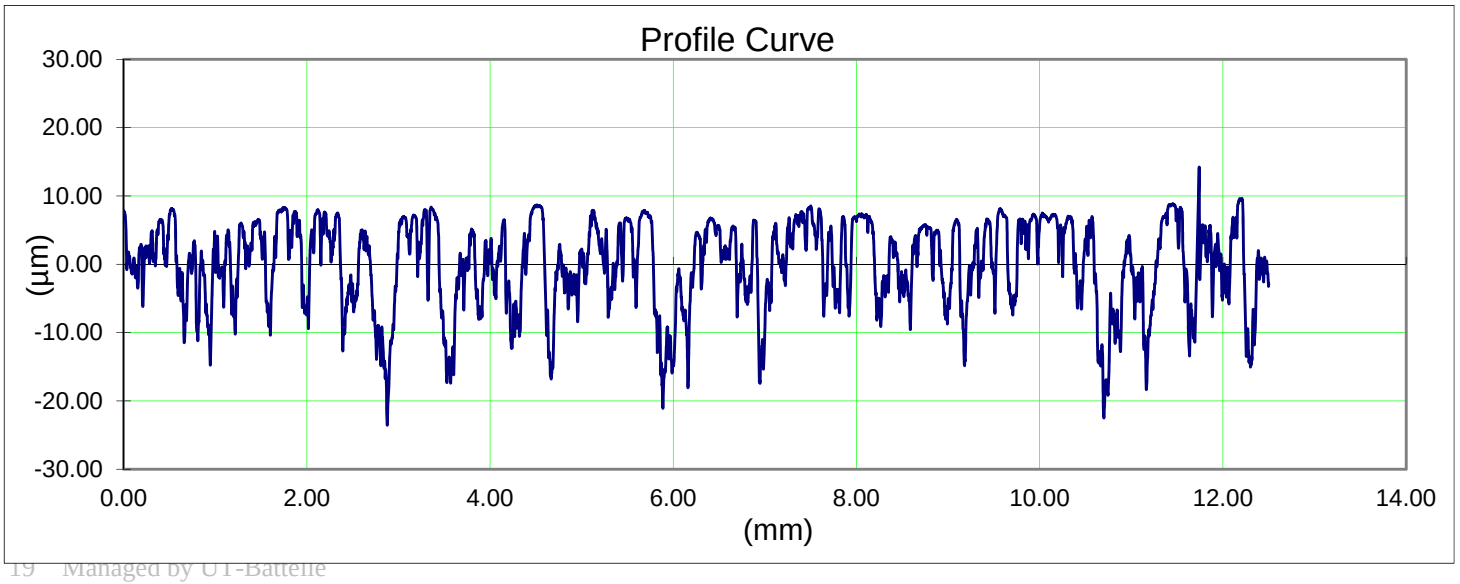
Viewport 2 Scans 3-4

P2_03



Ra	4.69	Rmr	2.3
Rmax	28.84	Rk	15.78
Rz	24.30	Rpk	2.38
RSm	256.50	Rvk	6.74
Rq	5.71	Mr1	5.3
Rpm	10.12	Mr2	86.1
Rp	13.64	Vo	0.0469
Rt	32.54	K	0.43
Pc	109		

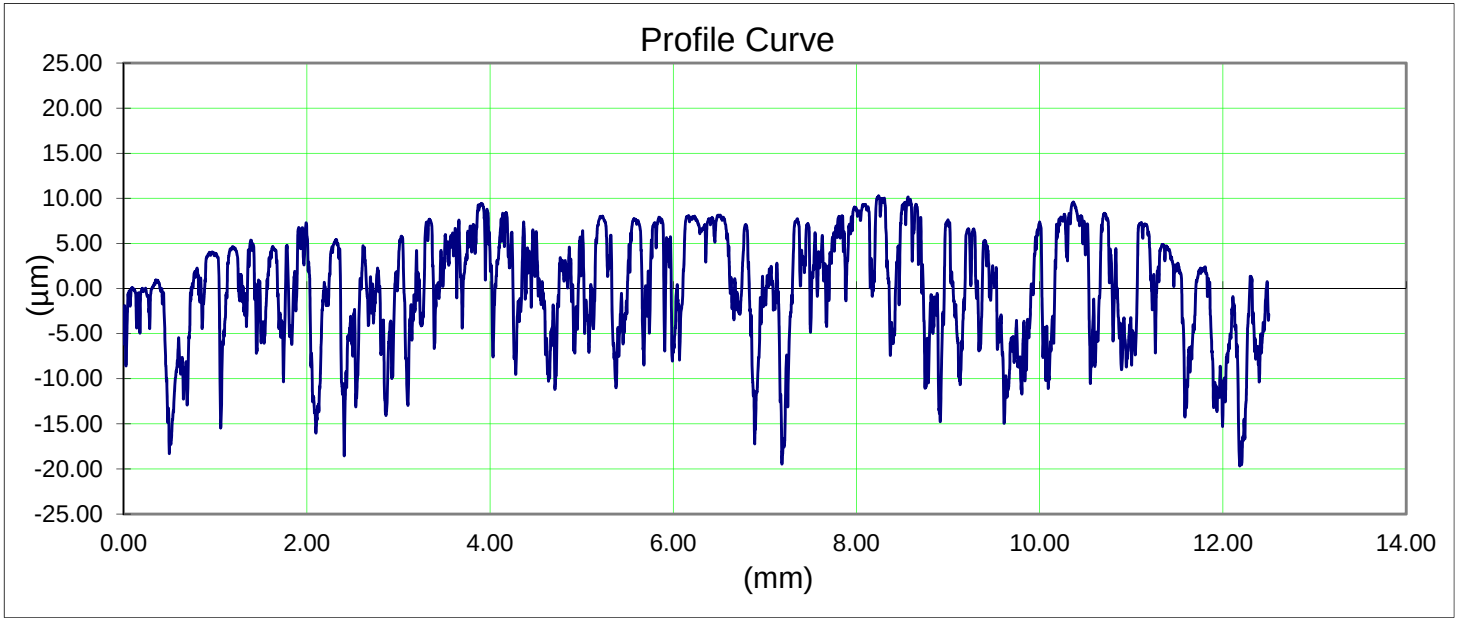
P2_04



Ra	4.17	Rmr	0.1
Rmax	26.82	Rk	11.53
Rz	21.45	Rpk	1.7
RSm	209.80	Rvk	7.91
Rq	5.07	Mr1	4.8
Rpm	8.22	Mr2	79.4
Rp	13.92	Vo	0.0817
Rt	31.64	K	0.69
Pc	118		

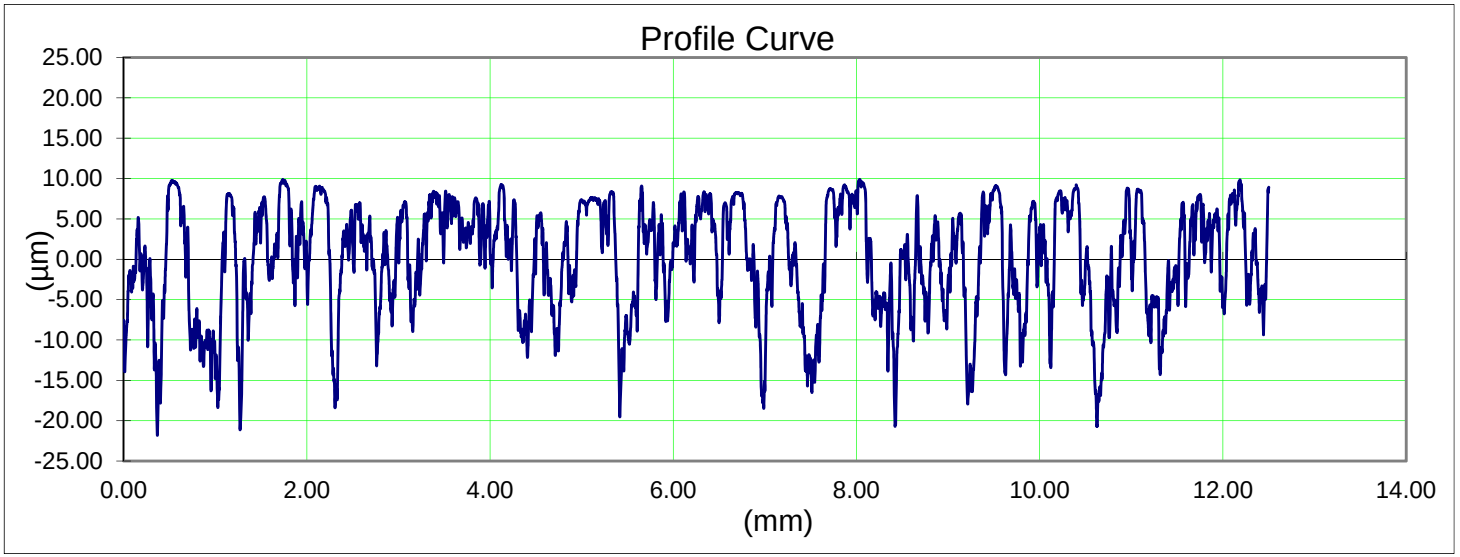
Viewport 2 Scans 5-6

P2_05



Ra	3.99	Rmr	8.8
Rmax	24.44	Rk	10.16
Rz	19.43	Rpk	1.31
RSm	264.70	Rvk	7.23
Rq	4.74	Mr1	5.1
Rpm	7.12	Mr2	76.7
Rp	9.20	Vo	0.0842
Rt	25.54	K	0.71
Pc	110		

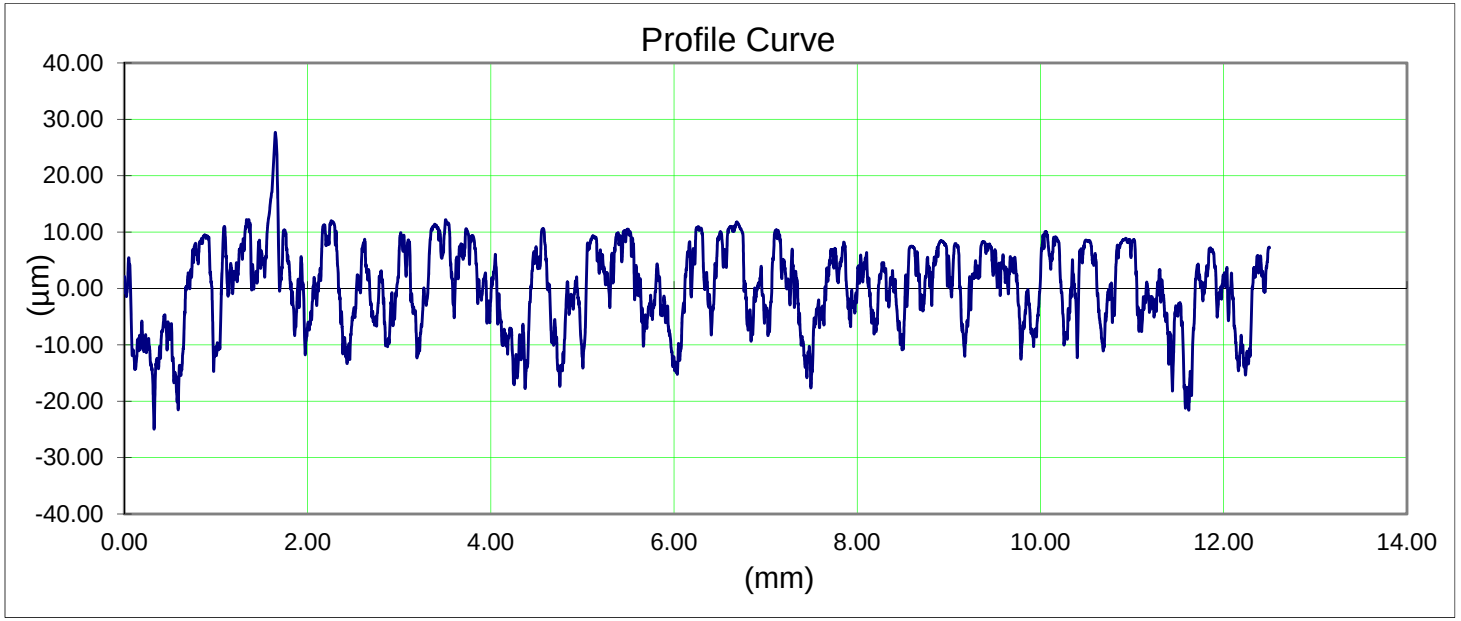
P2_06



Ra	4.38	Rmr	4.3
Rmax	31.02	Rk	13.68
Rz	22.45	Rpk	2.12
RSm	234.60	Rvk	7.79
Rq	5.31	Mr1	4.1
Rpm	8.50	Mr2	84.2
Rp	12.20	Vo	0.0615
Rt	31.10	K	0.57
Pc	117		

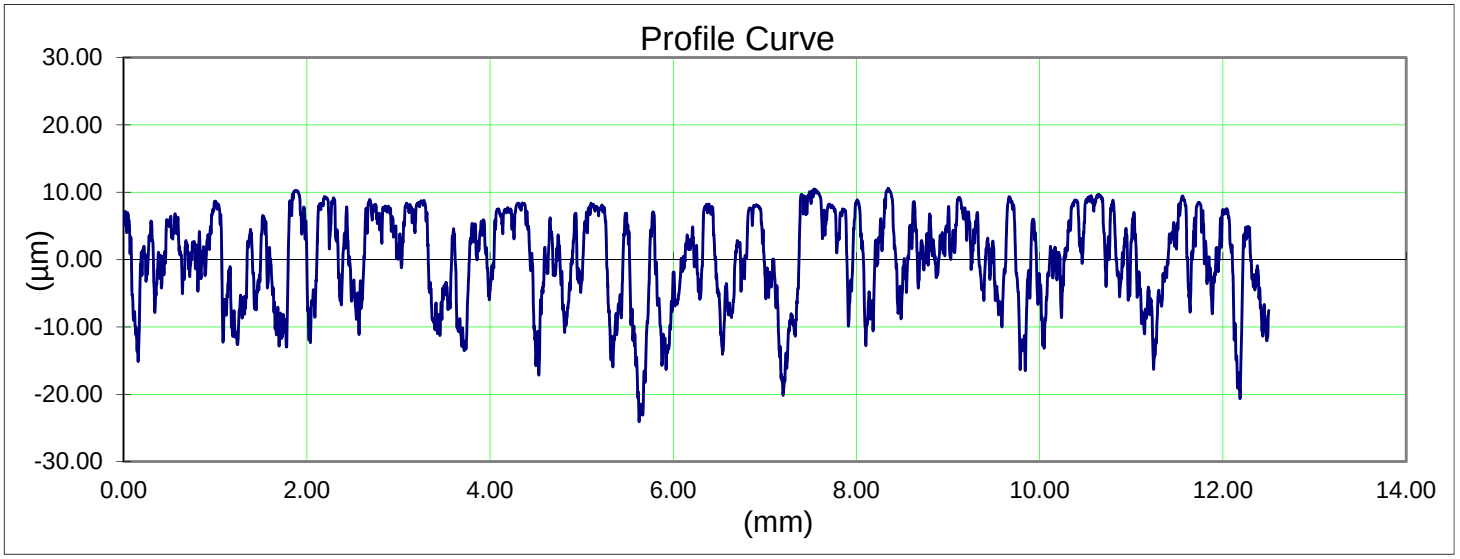
Viewport 2 Scans 7-8

P2_07



Ra	4.60	Rmr	0.2
Rmax	35.70	Rk	15.6
Rz	22.70	Rpk	4
RSm	246.40	Rvk	5.8
Rq	5.50	Mr1	2.8
Rpm	9.60	Mr2	85.7
Rp	19.40	Vo	0.0417
Rt	35.70	K	0.37
Pc	116		

P2_08



Ra	4.45	Rmr	0.5
Rmax	30.82	Rk	14.42
Rz	22.16	Rpk	2.27
RSm	228.60	Rvk	6.57
Rq	5.35	Mr1	3.6
Rpm	9.09	Mr2	83.7
Rp	15.42	Vo	0.0534
Rt	33.18	K	0.46
Pc	112		

Comments

- SNS specimens were polished to a roughness of a few microns prior to use – a known condition
  - Would like to compare scans from impacted specimens with those from unused specimens
- No distinguishable differences between any of the interior scan profiles of MERIT chamber, whether around a viewport or not
- Scan patterns seem to correlate to the “mottled” surface appearance from photographs
- Detecting minute pits in a rough surface is practically impossible using mechanical means