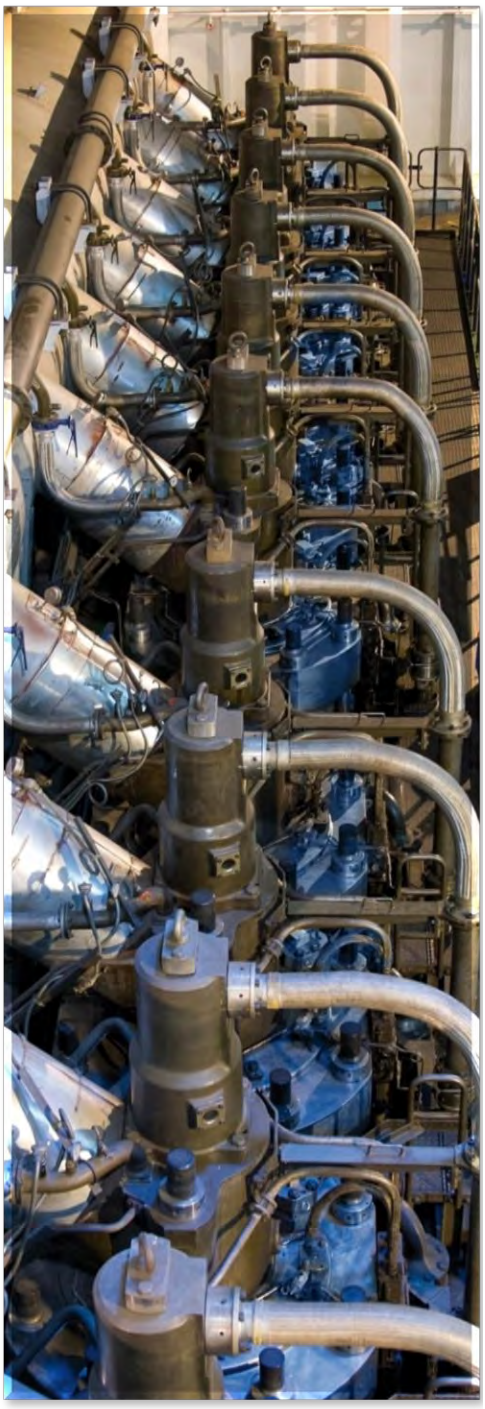


Inspection Report

Document subject:
Cylinder liner inspection, Anonymous vessel @ 142,394 Engine hours

Author:
Daniel Grunditz
Tel: +46 702 276900
daniel.grunditz@chris-marine.com

Date of measurement:
August 31st 2020

Summary

Chris-Marine Sweden carried out cylinder liner measurements, took pictures of liners and rings and collected replicas @142,394 Eh.

The maximum cylinder liner wear level was measured to 0.99-3.30 mm in the different units, with an average wear level of 1.71 mm. All units consistently display the highest wear level in the P-S direction, with a tendency to form sharp or very sharp trumpet shape / wear edge in the upper part of the liner. The sharpness of the trumpet increases with the maximum wear level as seen in the summary table.
The average liner wear rate since installation was found to be normal, varying from 0.02 to 0.08 mm/1000Rh in the different units, with an average wear rate of 0.04 mm/1000Rh. This average wear rate is comparable to the average level seen in measurements on other engines of the same type.

However, the cylinder condition is deteriorating in several units for this engine. Unit #6 is clearly scuffing at the moment (the current liner wear rate is most likely much higher than the average wear rate indicates) and some units have formed local scuff marks and black deposits and a mat cylinder surface according to liner pictures.
Several units also have a tendency of hard contact on the 1st piston ring. Such hard contact is likely to develop into scuffing unless actions are taken.
No units have a wave-cut pattern left, meaning that lubrication now depends entirely on the open graphite structure in the liner surface. Honing / wave-cut reconditioning and installation of cermet-coated piston rings will both make the cylinder condition more robust toward scuffing, so these actions should be considered for all units.
Some cat fines were observed in the liner surface, but not to an alarming level so the HFO purification system seems to work well.

Cylinder condition summary with remarks in red – see next page

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Max allowable wear (mm)	4.8		[redacted]								
Date	Liner installed @engine hours	2020-08-31 liner wear level [mm]		Liner Rh	Liner wear rate since new [mm/1000Rh]	Liner profile (from measurement)	Liner appearance from photos	Liner microstructure (replicas)	Piston ring condition from pictures	Cermet coating thickness, top ring [microns]	Recommendation
Engine hours		142394									
Cylinder #1	96397	1.35		45997	0.03	Sharp trumpet in upper part, max wear on 1st ring. Negligible ovality / clover	Bright liner surface in good condition with minor black deposits. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 14 microns.	Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.	-	Honing / WC at next docking. Install cermet rings.
Cylinder #2	97634	1.09		44760	0.02	Trumpet forming in upper part, max wear constant on 1st-4th ring. Negligible ovality / clover	Mat liner surface in good condition with minor black deposits. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 15 microns.	Ring pack in good condition. No coke deposits.	-	Honing / WC at next docking. Install cermet rings.
Cylinder #3	73017	3.30		69377	0.05	Very sharp trumpet in upper part, max wear on 4th ring. Significant ovality / clover	Bright liner surface in good condition with some black deposits. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. No visible cat fines.	Ring pack in good condition. No coke deposits.	254	Honing / WC as soon as possible. Install cermet rings.
Cylinder #4	96414	1.33		45980	0.03	Sharp trumpet in upper part, max wear on 1st ring. Negligible ovality / clover	Mat liner surface with some black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 13 microns.	Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.	-	Honing / WC at next docking. Install cermet rings.
Cylinder #5	96431	1.19		45963	0.03	Minor trumpet in upper part, max wear on 2nd ring. Negligible ovality / clover	Mat liner surface with some black deposits. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 16 microns.	Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.	-	Honing / WC at next docking. Install cermet rings.
Cylinder #6	104047	2.99		38347	0.08	Typical scuffing profile	Mat liner surface with some black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.	Cylinder scuffing with partially developed network of micro-cracks. A few visible cat fines.	1st and 2nd rings appear to have been over-heated.	-	Immediate honing or replacement. Install cermet rings.
Cylinder #7	97681	0.99		44713	0.02	Sharp trumpet in upper part, max wear on 1st ring. Negligible ovality / clover	Mat liner surface with black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 14 microns.	Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.	-	Honing / WC at next docking. Install cermet rings.
Cylinder #8	104433	1.40		37961	0.04	Very sharp trumpet in upper part, max wear close to 4th ring. Significant ovality / clover	Mat liner surface with black deposits. No wave-cut visible. Exhaust valve in good condition, but with some black deposits.	Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 17 microns.	Ring pack in good condition. No coke deposits.	-	Honing / WC at next docking. Install cermet rings.
Average		1.71			0.04						

Chris-Marine recommendations based on the current inspection:

- Immediate honing and optionally also wave-cut grinding or replacement of unit #6 is needed as it is currently scuffing. The scuffing is yet not clearly visible on rings, but micro-cracks have formed in the liner surface as a result of over-heating.

- Honing and optionally also wave-cut grinding or replacement of unit #3 should be planned as soon as possible, as the cylinder condition is likely to deteriorate in the near future.

- Honing and optionally also wave-cut grinding is recommended for all other cylinders at the next docking, to restore the running surface, remove ovality, clover leafing, trumpet shape and sharp wear edges that can otherwise lead to cylinder condition issues such as broken piston rings & cylinder scuffing.

- Chris-Marine recommends using the VKS wear-edge grinder for machining the wear edge to prevent the top ring from interfering with the liner wear edge after overhaul. This is also applicable after honing. Do not use an angle grinder for removing the wear edge as this can damage the running surface in TDC1, the top dead center position for the first piston ring, i.e. the most critical part of the liner. More information on the VKS can be found on https://www.chris-marine.com/product/wear-edge-milling-machine-vks/

General MAN recommendations

- MAN recommends installing cermet-coated piston rings and using 15-40 TBN cylinder lube oils for all engines using <=0.5% S fuel oils (vessels without scrubbers). See sl2018-659 and sl2019-671 for details.

- The impact of fuel tank contamination by cat fines is described by MAN on sl2019-674

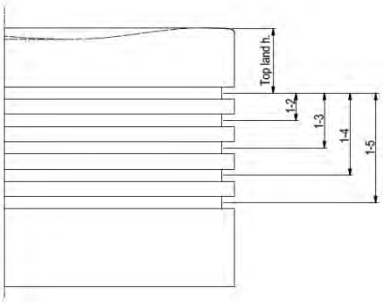
- Cat fines, drain oil analysis and lube oil feedrate optimization is well described by MAN in technical paper catfines-paper-5510-0207-00

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Vessel Details

- Vessel name: Anonymous
- DOC: XXX
- Year built: XXXX
- Speed recorded (Service): XXXX
- IMO: XXXXXXX
- Prime Mover Design: B&W
- Engine Builder: Korea Heavy Industries & Constr Co Ltd (HANJUNG) - South Korea
- 1 x 8S60MC, 2 Stroke, Single Acting, In-Line (Vertical)
- 8 Cy. 600 x 2292, Mcr: 16,358 kW (22,240 hp) at 105 rpm

Engine Dimensions and cylinder liner measurement depths



Bore	600
Stroke	2292
Top land height	202
Ring center distance, 1-2	33
Ring center distance, 1-3	60
Ring center distance, 1-4	86
Ring center distance, 1-5	0
Reference depth	1950
Depths, ring center related	-16, 0, 16, 33, 46, 60, 73, 86, 99
Depths, additional	1500, 1000, 500, 400, 300, 200
Wear ridge tracing	True

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Definitions

- Wear is defined as the difference between the current diameter and the unworn reference diameter. The nominal diameter, 600.00 mm, was used as reference for wear in this report.
- Maximum Wear Limit is defined by the engine maker. It is normally 0.8 % of the nominal diameter of the Liner, i.e. 4.8 mm for this engine.
- Ovality is the Difference between the Fore-Aft and Port-Starboard diameters on the same level.
- In the wear data table, the columns have the following meaning:
    - Id: Measurement Id and measurement order
    - Depth corr: Measurement depth measured downward from TDC1, i.e. from the level where the highest piston ring is switching directions from upward motion to downward motion.
    - P-S corr / F-A corr: Cylinder diameter wear in the Port-Starboard and Fore-Aft directions, respectively
    - P-S Dcyl corr / F-A Dcyl corr: Absolute cylinder diameter in the Port-Starboard and Fore-Aft directions, respectively
    - Ovality corr: Ovality
- In the clover plot, the legend shows the measurement depth for each clover measurement.
- If there is only one clover measurement, then measurement depth is also shown in the headline.

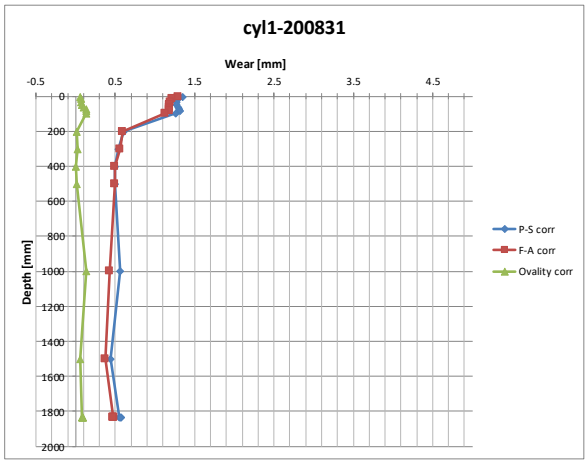
The clover measurement shows the contour of the cylinder liner in one or several measurement depths. It consists of 36 radial measurements every 10 degrees and is plotted on a polar graph showing the deviation from a pure circle in more detail. The purpose of the measurement is to analyse if cylinder honing will be needed for correcting the cylinder geometry, and to also trace possible root causes when there are deviations so that countermeasures can be made. The clover measurement is normally taken in the TDC position for the second piston ring, TDC2. The reason for choosing this position is to be close to the maximum wear level and at the same time avoid hitting coke deposits in top land in case the device is somewhat inclined during the measurement.

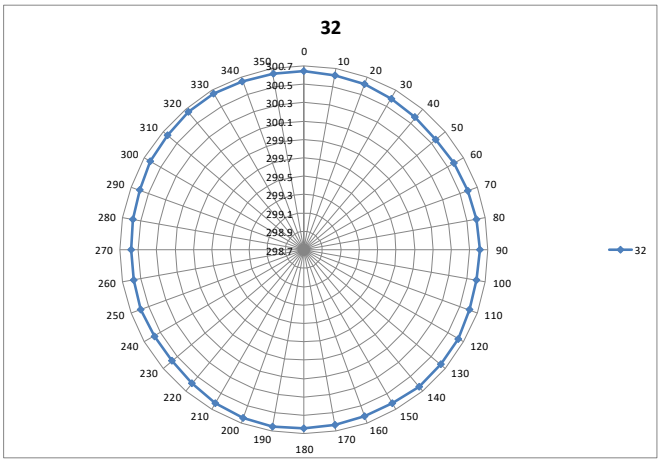
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder liner measurement results from the current inspection

Cylinder #1, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	0	1.35	1.29	601.35	601.29	0.06
14	14	1.29	1.22	601.29	601.22	0.07
13 (TDC2)	32	1.27	1.20	601.27	601.20	0.07
12	45	1.27	1.19	601.27	601.19	0.08
11 (TDC3)	61	1.29	1.19	601.29	601.19	0.10
10	74	1.31	1.18	601.31	601.18	0.13
9	82	1.32	1.19	601.32	601.19	0.13
8	98	1.26	1.13	601.26	601.13	0.13
7	199	0.60	0.59	600.60	600.59	0.01
6	301	0.54	0.56	600.54	600.56	0.02
5	400	0.49	0.49	600.49	600.49	0.00
4	497	0.50	0.49	600.50	600.49	0.01
3	998	0.56	0.43	600.56	600.43	0.13
2	1500	0.44	0.38	600.44	600.38	0.06
1 (Ref)	1831	0.55	0.47	600.55	600.47	0.08
1 (Ref)	1832	0.57	0.48	600.57	600.48	0.09
1 (Ref)	1832	0.57	0.48	600.57	600.48	0.09
1 (Ref)	1832	0.56	0.47	600.56	600.47	0.09
Max		**1.35**	**1.29**	**601.35**	**601.29**	**0.13**
Reference diameter				*600.00*	*600.00*	



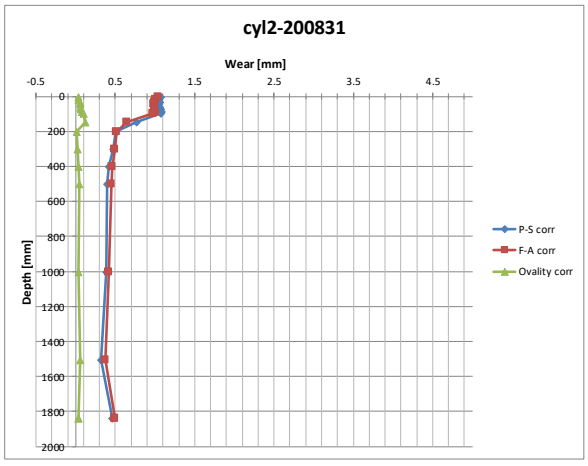


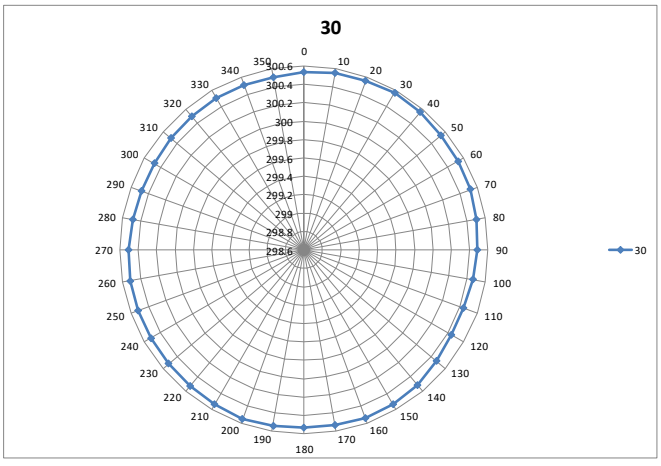
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl1
Generated 2020-10-22 07:55:16 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #2, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
16 (TDC1)	0	1.08	1.04	601.08	601.04	0.04
15	17	1.05	1.01	601.05	601.01	0.04
14 (TDC2)	31	1.06	1.00	601.06	601.00	0.06
13	44	1.05	0.99	601.05	600.99	0.06
12 (TDC3)	62	1.06	1.00	601.06	601.00	0.06
11	74	1.07	1.00	601.07	601.00	0.07
9 (TDC4)	88	1.09	1.01	601.09	601.01	0.08
8	97	1.08	0.98	601.08	600.98	0.10
10	144	0.77	0.65	600.77	600.65	0.12
7	203	0.51	0.52	600.51	600.52	0.01
6	301	0.47	0.49	600.47	600.49	0.02
5	402	0.42	0.46	600.42	600.46	0.04
4	498	0.40	0.45	600.40	600.45	0.05
3	1000	0.39	0.42	600.39	600.42	0.03
2	1504	0.32	0.38	600.32	600.38	0.06
1 (Ref)	1836	0.46	0.50	600.46	600.50	0.04
1 (Ref)	1837	0.46	0.49	600.46	600.49	0.03
Max		**1.09**	**1.04**	**601.09**	**601.04**	**0.12**
Reference diameter				***600.00***	***600.00***	



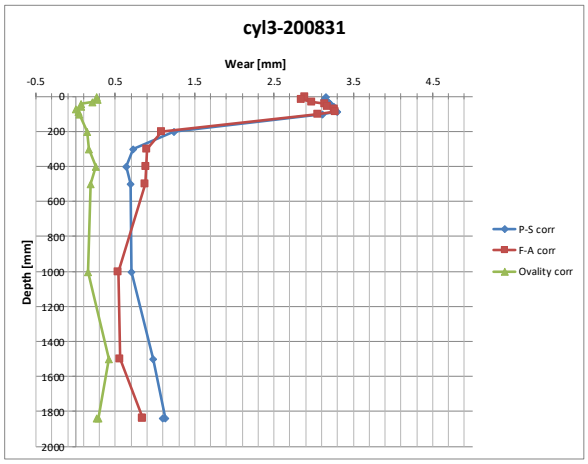


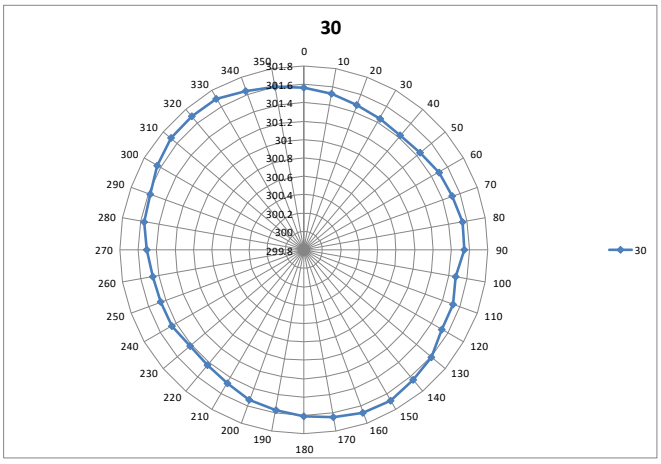
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl2
Generated 2020-10-22 07:55:19 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #3, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	1	3.15	2.89	603.15	602.89	0.26
14	16	3.13	2.85	603.13	602.85	0.28
13 (TDC2)	31	3.19	2.98	603.19	602.98	0.21
12	43	3.21	3.14	603.21	603.14	0.07
11 (TDC3)	59	3.25	3.18	603.25	603.18	0.07
10	70	3.26	3.26	603.26	603.26	0.00
9 (TDC4)	88	3.30	3.27	603.30	603.27	0.03
8	99	3.11	3.06	603.11	603.06	0.05
7	201	1.24	1.09	601.24	601.09	0.15
6	302	0.73	0.90	600.73	600.90	0.17
5	400	0.64	0.89	600.64	600.89	0.25
4	501	0.69	0.88	600.69	600.88	0.19
3	1001	0.70	0.54	600.70	600.54	0.16
2	1500	0.98	0.56	600.98	600.56	0.42
1 (Ref)	1836	1.13	0.84	601.13	600.84	0.29
1 (Ref)	1836	1.10	0.84	601.10	600.84	0.26
Max		**3.30**	**3.27**	**603.30**	**603.27**	**0.42**
Reference diameter				*600.00*	*600.00*	



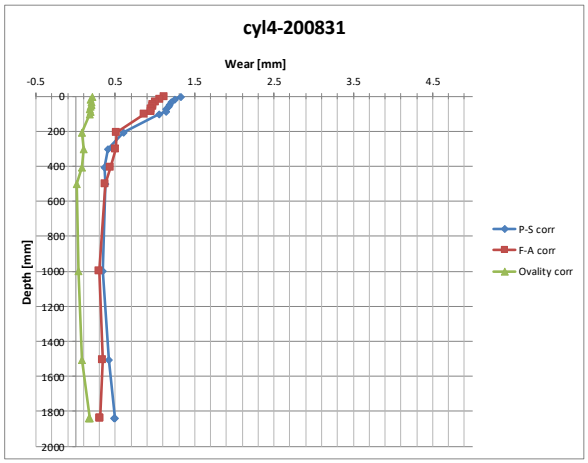


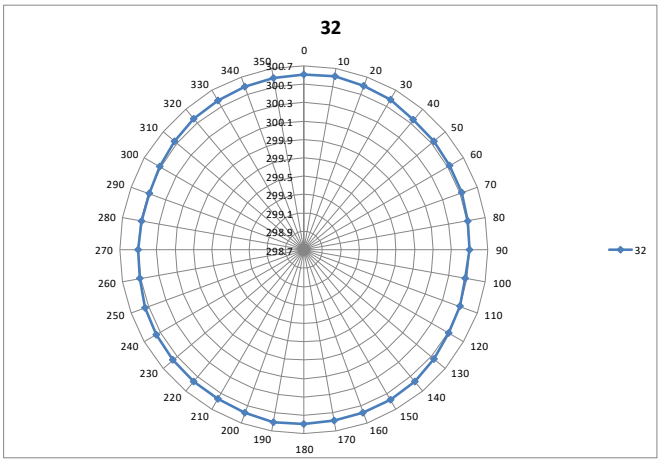
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl3
Generated 2020-10-22 07:55:23 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #4, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	1	1.33	1.12	601.33	601.12	0.21
14	15	1.25	1.06	601.25	601.06	0.19
13 (TDC2)	32	1.21	1.01	601.21	601.01	0.20
12	45	1.18	0.98	601.18	600.98	0.20
11 (TDC3)	57	1.17	0.98	601.17	600.98	0.19
10	74	1.14	0.96	601.14	600.96	0.18
9 (TDC4)	86	1.14	0.95	601.14	600.95	0.19
8	101	1.05	0.87	601.05	600.87	0.18
7	204	0.60	0.52	600.60	600.52	0.08
6	301	0.41	0.51	600.41	600.51	0.10
5	403	0.36	0.44	600.36	600.44	0.08
4	499	0.38	0.37	600.38	600.37	0.01
3	999	0.34	0.30	600.34	600.30	0.04
2	1502	0.42	0.34	600.42	600.34	0.08
1 (Ref)	1836	0.49	0.31	600.49	600.31	0.18
1 (Ref)	1836	0.48	0.31	600.48	600.31	0.17
Max		**1.33**	**1.12**	**601.33**	**601.12**	**0.21**
Reference diameter				***600.00***	***600.00***	



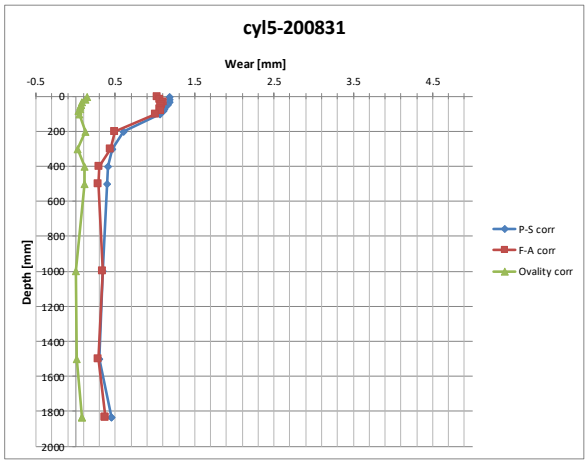


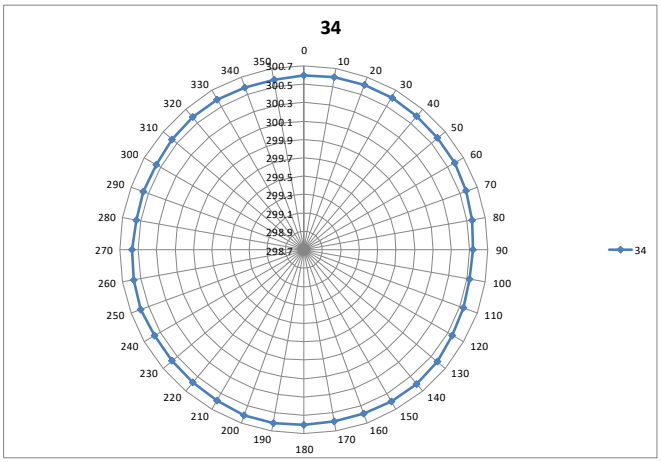
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl4
Generated 2020-10-22 07:55:27 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #5, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	1	1.18	1.03	601.18	601.03	0.15
14	16	1.18	1.06	601.18	601.06	0.12
13 (TDC2)	32	1.19	1.11	601.19	601.11	0.08
12	45	1.16	1.09	601.16	601.09	0.07
11 (TDC3)	59	1.13	1.07	601.13	601.07	0.06
10	71	1.12	1.06	601.12	601.06	0.06
9 (TDC4)	83	1.11	1.07	601.11	601.07	0.04
8	99	1.06	1.01	601.06	601.01	0.05
7	203	0.61	0.49	600.61	600.49	0.12
6	298	0.46	0.44	600.46	600.44	0.02
5	400	0.41	0.30	600.41	600.30	0.11
4	497	0.40	0.29	600.40	600.29	0.11
3	999	0.34	0.34	600.34	600.34	0.00
2	1500	0.30	0.29	600.30	600.29	0.01
1 (Ref)	1832	0.45	0.37	600.45	600.37	0.08
1 (Ref)	1832	0.45	0.37	600.45	600.37	0.08
Max		**1.19**	**1.11**	**601.19**	**601.11**	**0.15**
Reference diameter				*600.00*	*600.00*	



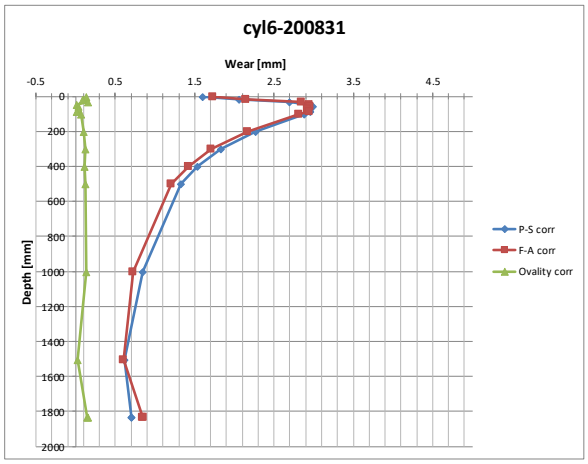


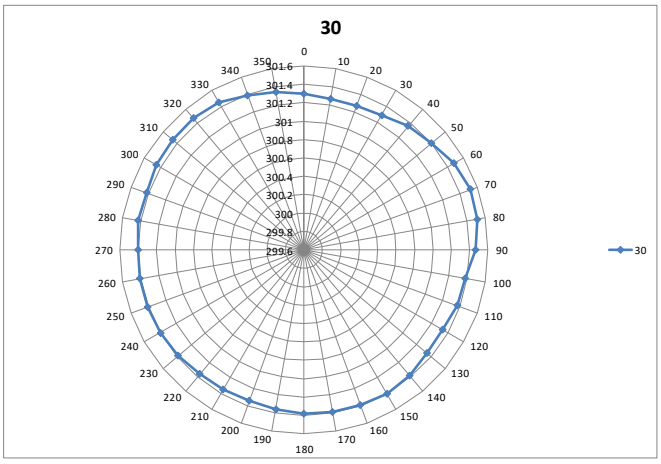
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl5
Generated 2020-10-22 07:55:31 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #6, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	0	1.60	1.73	601.60	601.73	0.13
14	16	2.06	2.15	602.06	602.15	0.09
13 (TDC2)	31	2.69	2.85	602.69	602.85	0.16
12	48	2.94	2.95	602.94	602.95	0.01
11 (TDC3)	59	2.99	2.96	602.99	602.96	0.03
10	71	2.96	2.92	602.96	602.92	0.04
9 (TDC4)	85	2.96	2.95	602.96	602.95	0.01
8	99	2.88	2.81	602.88	602.81	0.07
7	200	2.27	2.17	602.27	602.17	0.10
6	302	1.83	1.71	601.83	601.71	0.12
5	402	1.53	1.42	601.53	601.42	0.11
4	501	1.33	1.21	601.33	601.21	0.12
3	1000	0.85	0.72	600.85	600.72	0.13
2	1502	0.62	0.60	600.62	600.60	0.02
1 (Ref)	1832	0.70	0.85	600.70	600.85	0.15
1 (Ref)	1832	0.70	0.86	600.70	600.86	0.16
Max		**2.99**	**2.96**	**602.99**	**602.96**	**0.16**
Reference diameter				*600.00*	*600.00*	



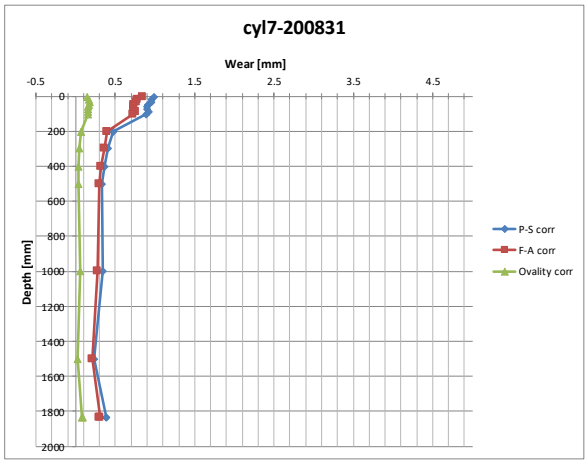


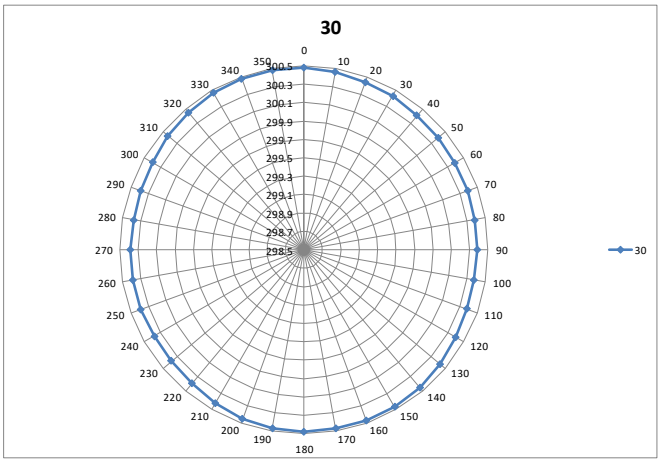
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl6
Generated 2020-10-22 07:55:35 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #7, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	1	0.99	0.84	600.99	600.84	0.15
14	16	0.95	0.78	600.95	600.78	0.17
13 (TDC2)	30	0.95	0.77	600.95	600.77	0.18
12	46	0.91	0.74	600.91	600.74	0.17
11 (TDC3)	58	0.90	0.74	600.90	600.74	0.16
10	71	0.90	0.74	600.90	600.74	0.16
9 (TDC4)	85	0.92	0.76	600.92	600.76	0.16
8	99	0.89	0.73	600.89	600.73	0.16
7	200	0.47	0.40	600.47	600.40	0.07
6	297	0.41	0.36	600.41	600.36	0.05
5	399	0.36	0.32	600.36	600.32	0.04
4	498	0.33	0.30	600.33	600.30	0.03
3	999	0.34	0.28	600.34	600.28	0.06
2	1498	0.23	0.21	600.23	600.21	0.02
1 (Ref)	1834	0.39	0.31	600.39	600.31	0.08
1 (Ref)	1834	0.39	0.30	600.39	600.30	0.09
Max		**0.99**	**0.84**	**600.99**	**600.84**	**0.18**
Reference diameter				***600.00***	***600.00***	



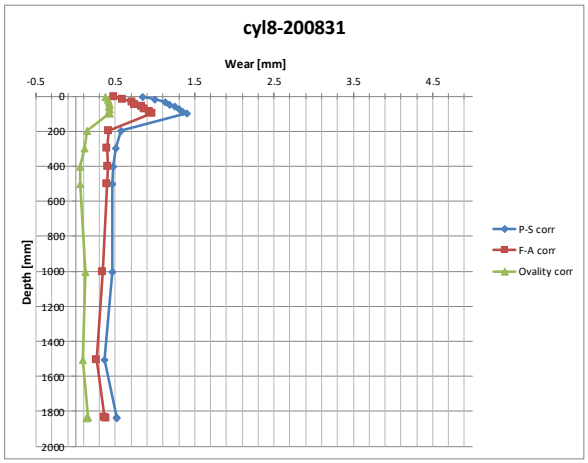


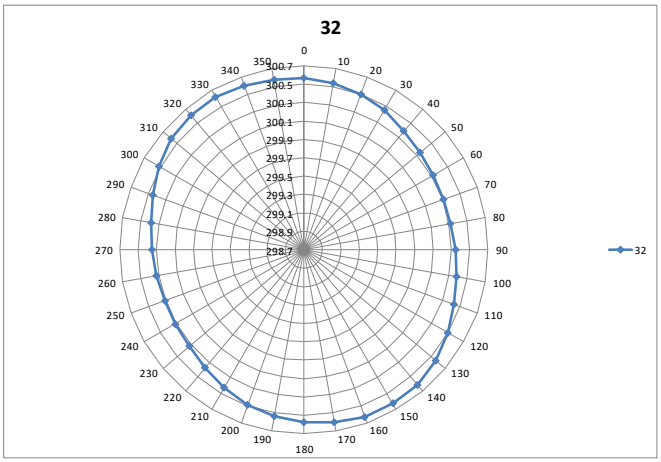
Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl7
Generated 2020-10-22 07:55:39 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #8, LDM measurement results

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
15 (TDC1)	1	0.85	0.48	600.85	600.48	0.37
14	17	1.00	0.59	601.00	600.59	0.41
13 (TDC2)	31	1.13	0.71	601.13	600.71	0.42
12	45	1.18	0.75	601.18	600.75	0.43
11 (TDC3)	59	1.25	0.83	601.25	600.83	0.42
10	74	1.30	0.87	601.30	600.87	0.43
9 (TDC4)	85	1.35	0.93	601.35	600.93	0.42
8	98	1.40	0.97	601.40	600.97	0.43
7	198	0.57	0.42	600.57	600.42	0.15
6	297	0.51	0.40	600.51	600.40	0.11
5	401	0.47	0.41	600.47	600.41	0.06
4	498	0.46	0.40	600.46	600.40	0.06
3	1000	0.46	0.34	600.46	600.34	0.12
2	1502	0.36	0.27	600.36	600.27	0.09
1 (Ref)	1834	0.52	0.36	600.52	600.36	0.16
1 (Ref)	1836	0.52	0.39	600.52	600.39	0.13
Max		**1.40**	**0.97**	**601.40**	**600.97**	**0.43**
Reference diameter				***600.00***	***600.00***	





Report filename [Anonymous-200831.PostProc.xlsm], sheet Cyl8
Generated 2020-10-22 07:55:43 by LDM PPT

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Microscopy analysis of replicas, introduction

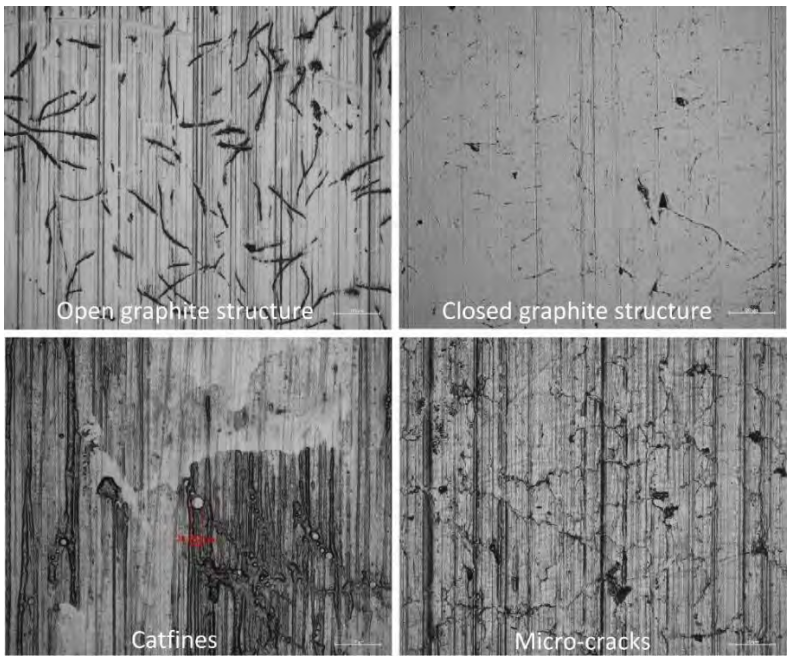
Microscopic images of replicas taken just above the scavenge ports during LDM measurements under cover-on conditions, or at the top of the cylinder liner under cover-off conditions, give a good overview of the current wear situation for each cylinder. Chris-Marine has compared replicas taken at the top of the liner to samples taken from the scavenge port level and found that the two methods produce comparable results.

A closed graphite structure is sometimes referred to as bore polish since it has been generated from polished compounds of Ferrite (from liner material), topland coke deposits (from fuel and lube combustion products) or excess of neutralizing agents in the lubrication oil. A closed graphite structure means that a lubrication oil film will not be sustained unless there are mechanical patterns from honing or other grooves acting as oil reservoirs in the liner surface. Closed graphite structure can be caused by under-lubrication (oil starvation) as well as over-lubrication (excess of neutralizing agents in the lubrication oil). Bore polish / closed graphite structure is a pre-cursor for scuffing.

Scuffing occurs when the lubrication film breaks down completely, putting piston rings in mechanical contact with liner wall. The frictional heat generated will then cause overheating and local thermal expansion of liner surface and piston rings. The result is micro-cracks in the liner surface and on piston rings which can be seen very clearly under microscope. Particles eventually break out of the micro-cracked surfaces thereby causing the wear rate to accelerate. Once scuffing has occurred, there is no way for the system to self-heal. Cylinder liners must then be honed and piston rings replaced for the system to normalize. The wear rate during scuffing can be up to 100 times higher than under normal conditions.

Cat fines are very abrasive residues from the refinery process, present in residual fuel oil (petroleum products that have not vaporized through cracking). Cat fines are easy to identify under microscope as they are completely spherical. The cat fines normally reside within the soft open graphite structure. Cat fines larger than ~15 microns or cat fines occurring at high frequency indicate a mal-functioning HFO fuel purification system. Fuel oil storage tanks, service tanks and separators then need maintenance. The concentration of cat fines at engine entry should be less than 15 ppm according to engine makers, whereas the concentration of cat fines in the sediment of a fuel storage tank can be several thousand ppm. This means that a greatly contaminated fuel storage tank can never be completely compensated by a very well-working separation and filtration system. This is why it is not always sufficient to maintain separators and filters, but also necessary to keep storage tanks free from sediment. The cat fines greatly accelerate the liner and piston ring wear rates and can lead to scuffing.

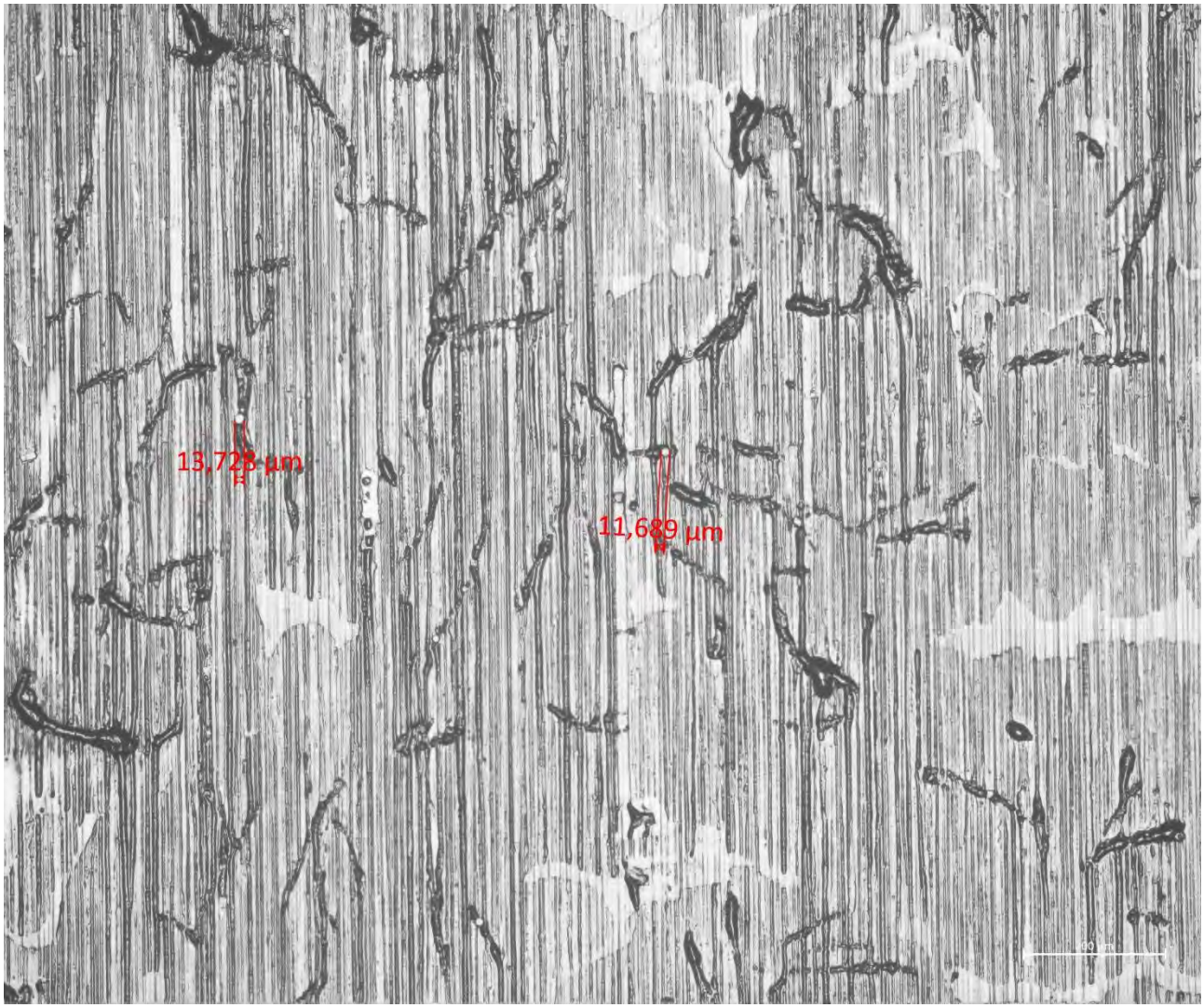
Examples of open and closed liner structures, micro-cracks and cat fines are shown below.



Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Microscopy analysis of replicas from the current inspection

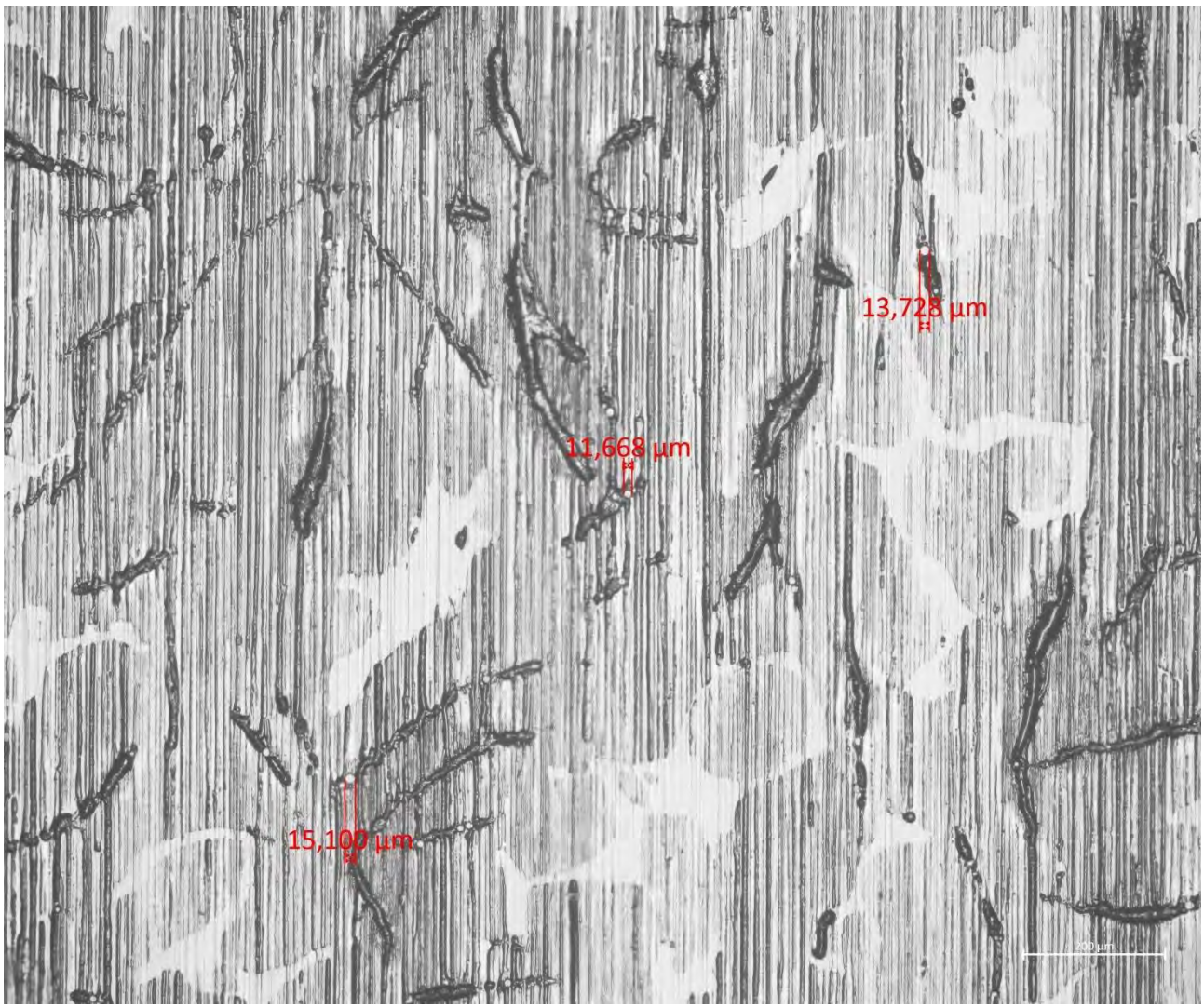
Cylinder #1 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 14 microns.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

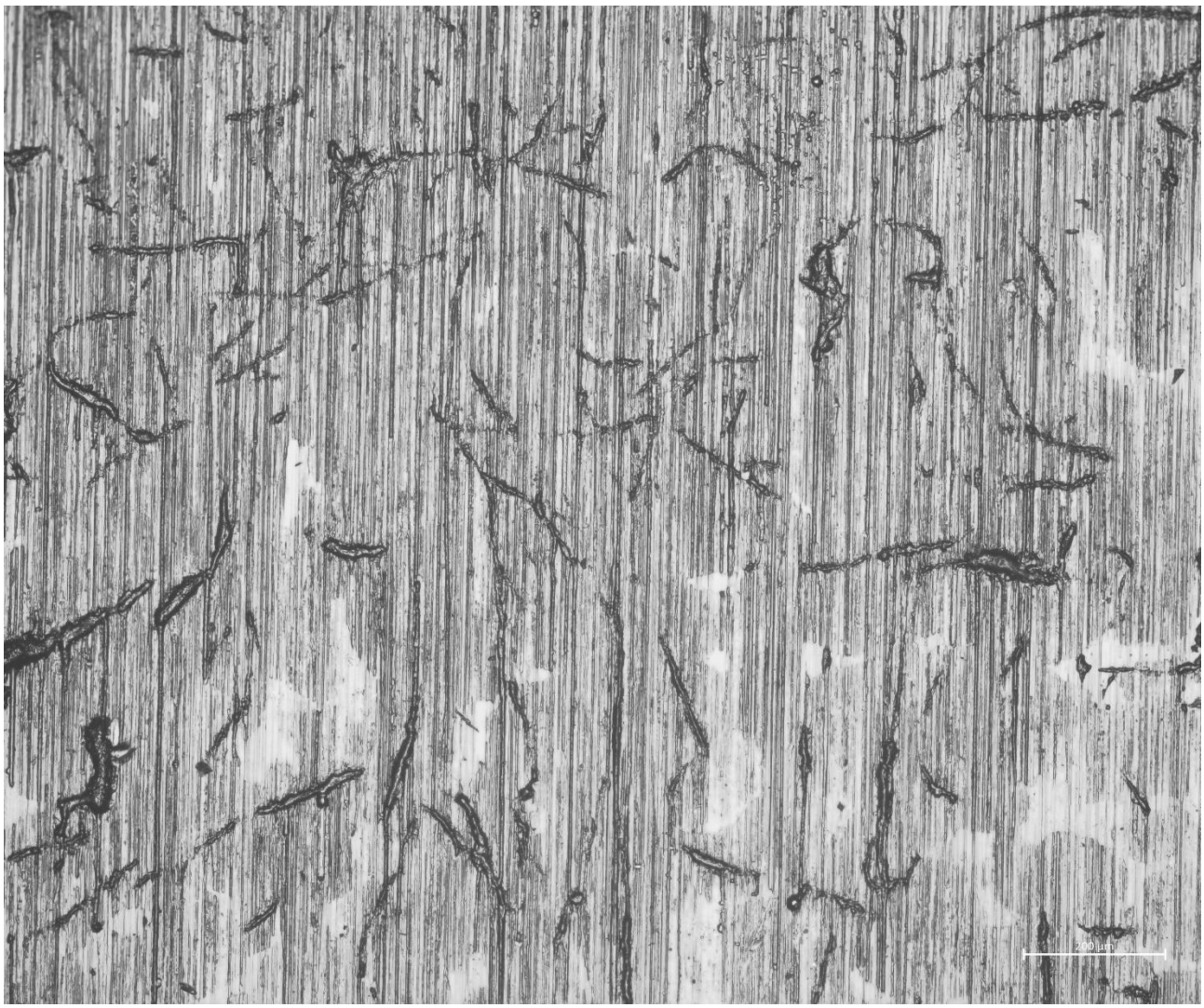
Cylinder #2 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 15 microns.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

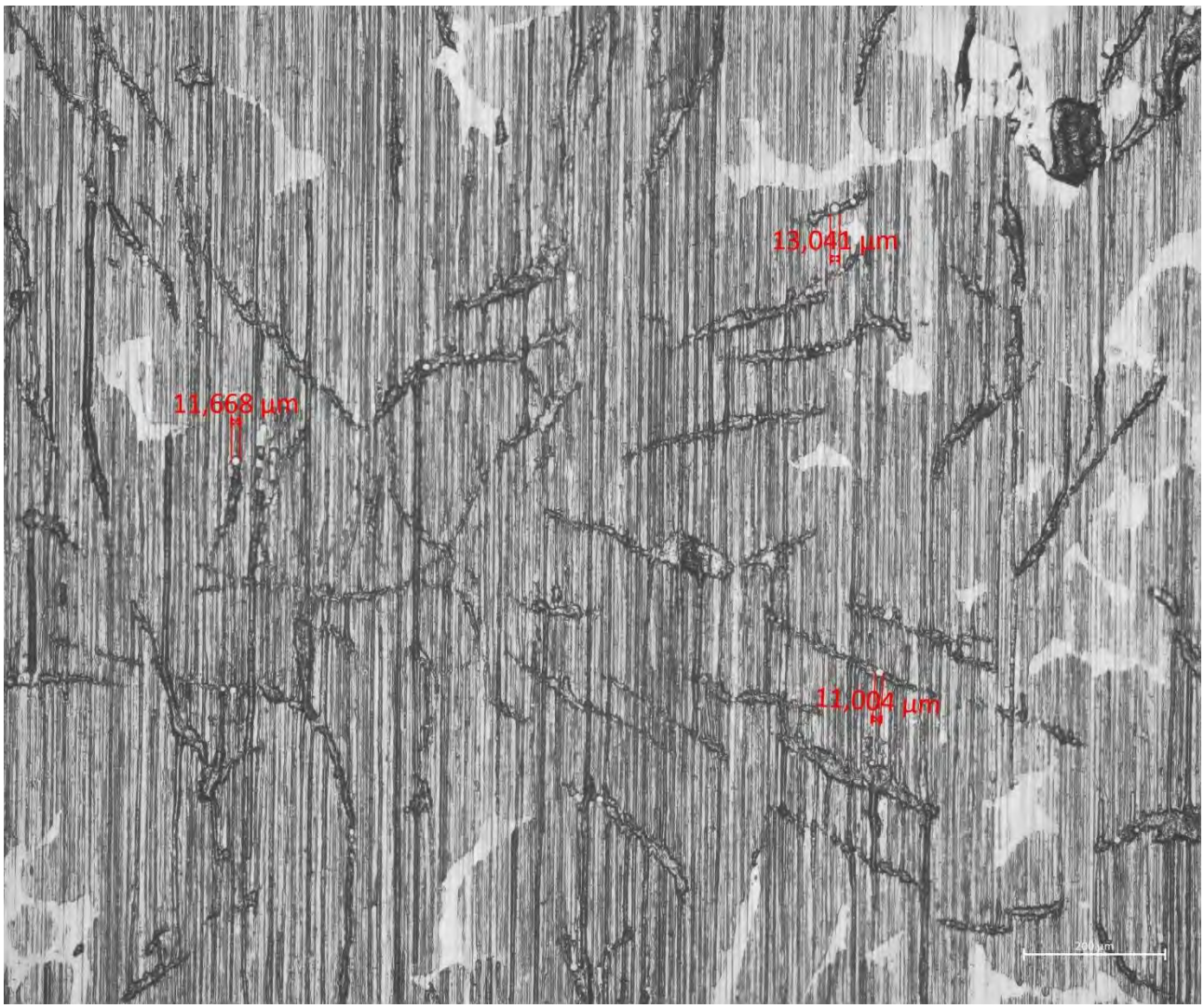
Cylinder #3 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. No visible cat fines.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

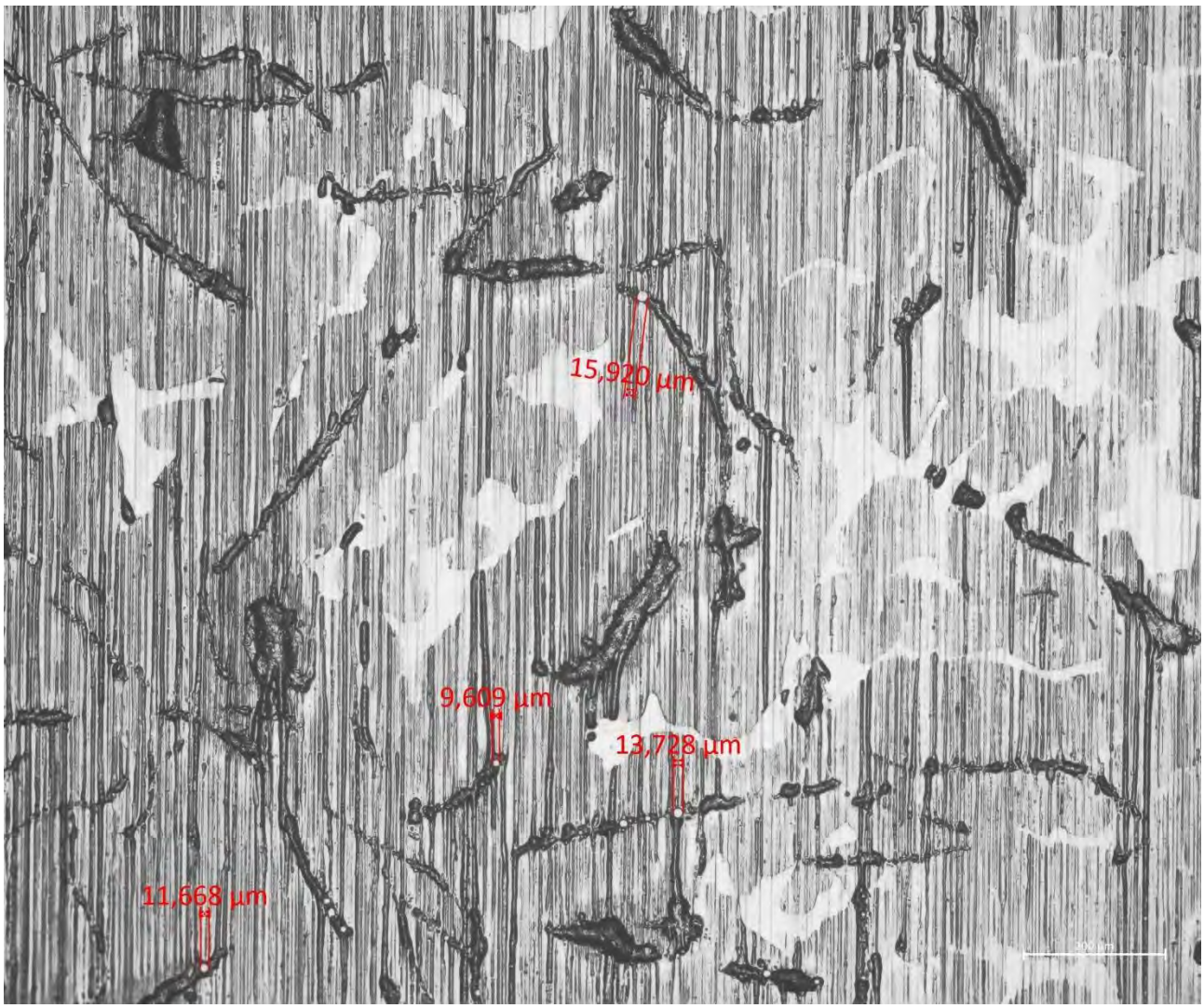
Cylinder #4 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 13 microns.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

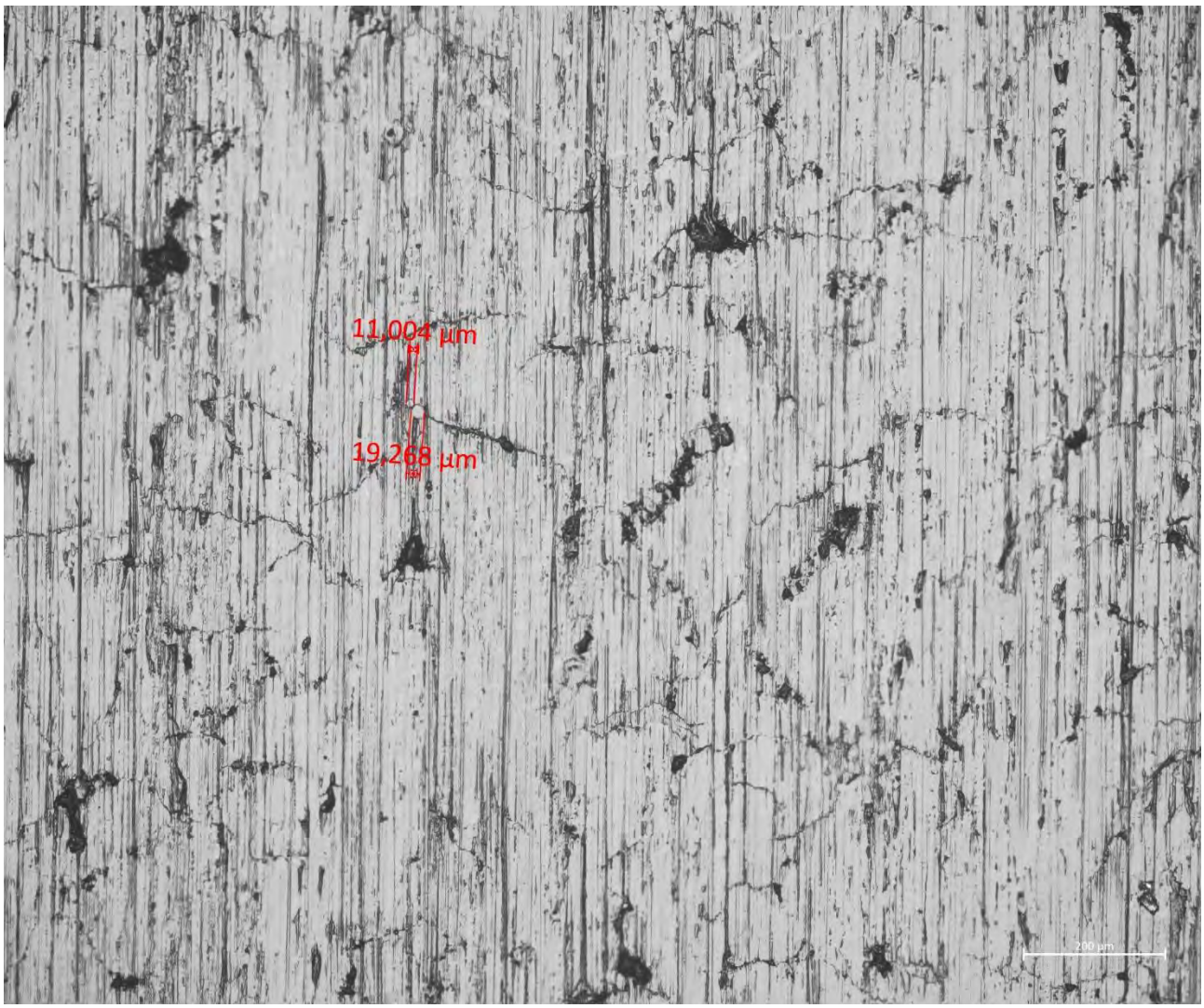
Cylinder #5 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 16 microns.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

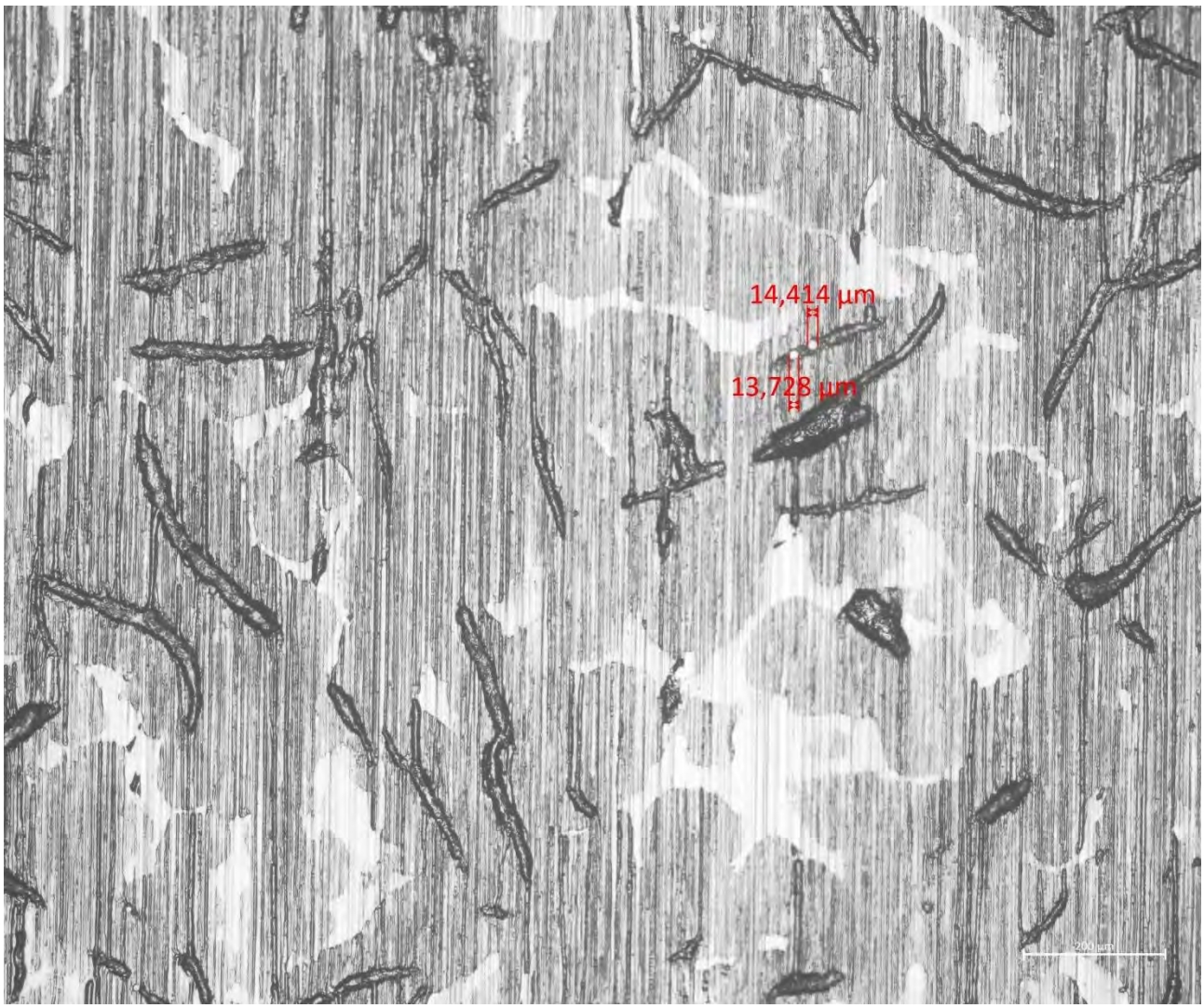
Cylinder #6 - 10x magnification



Observations: Cylinder scuffing with partially developed network of micro-cracks. A few visible cat fines.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

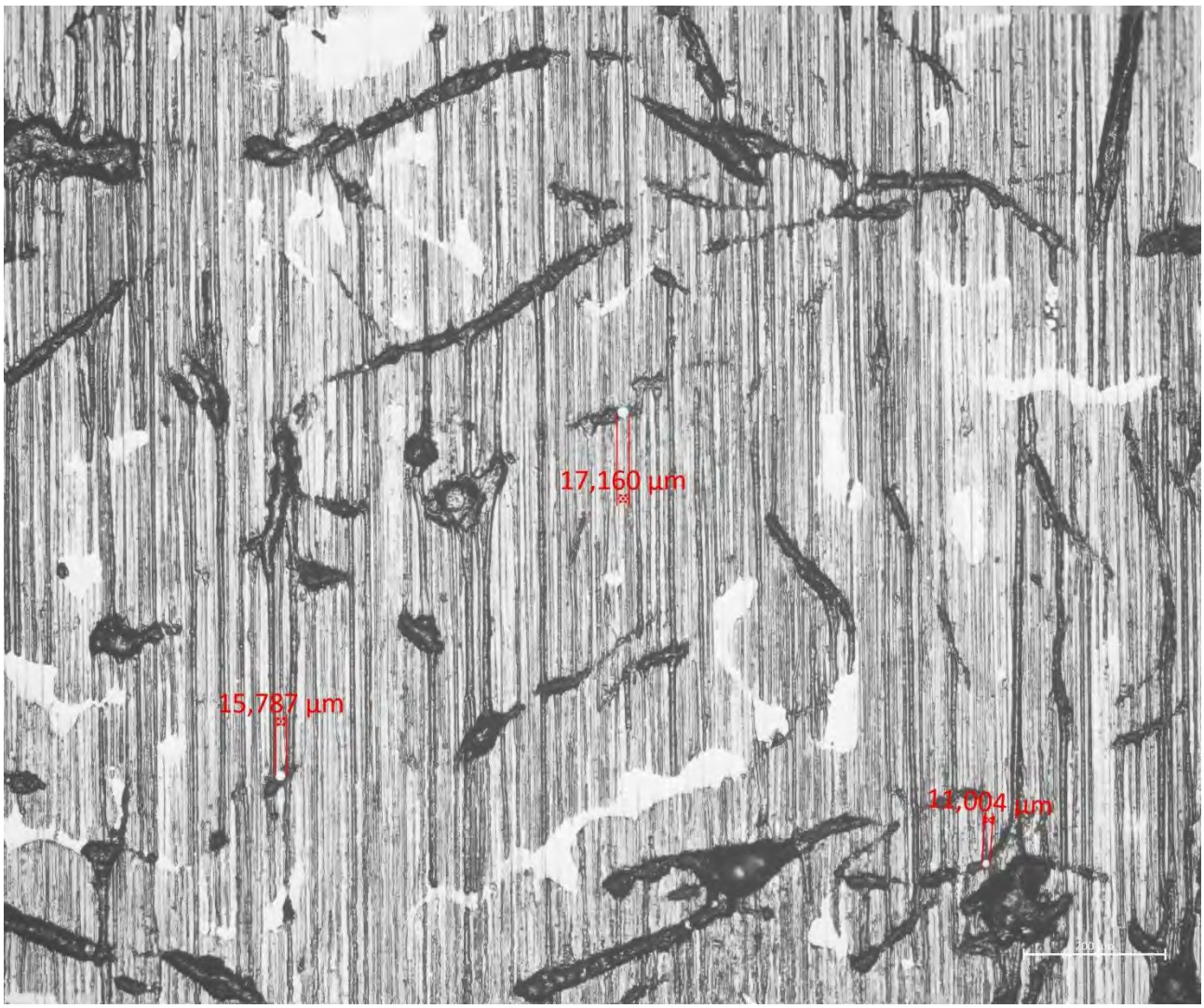
Cylinder #7 - 10x magnification



Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 14 microns.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Cylinder #8 - 10x magnification

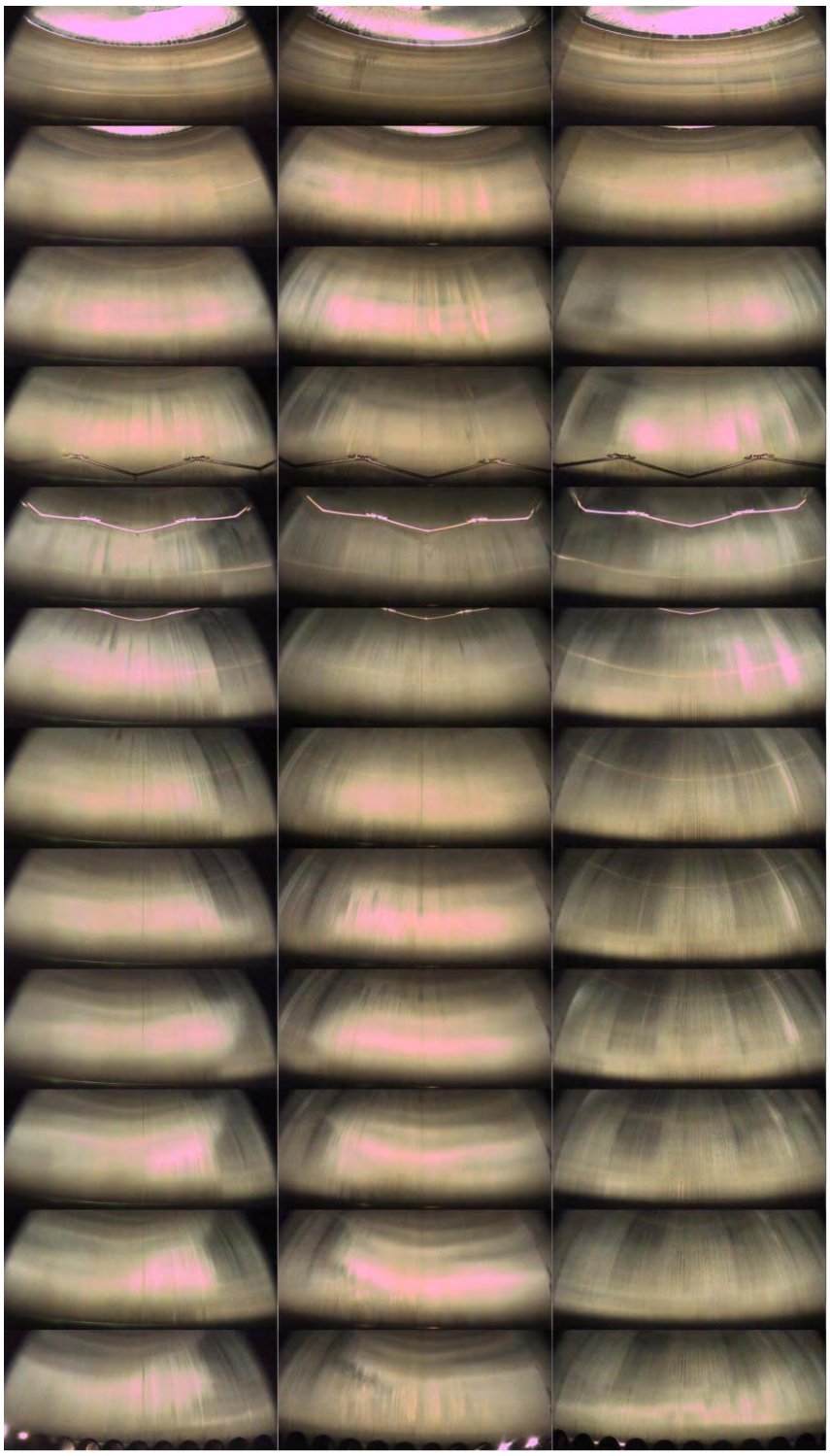


Observations: Normal, abrasive wear pattern and open graphite structure. A few visible cat fines, the largest being 17 microns.

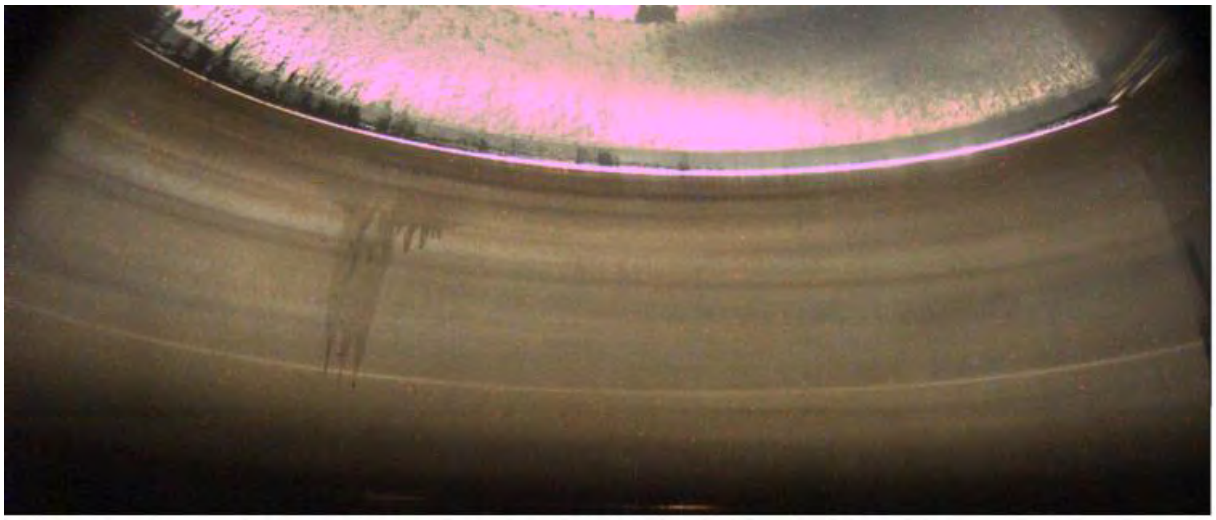
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

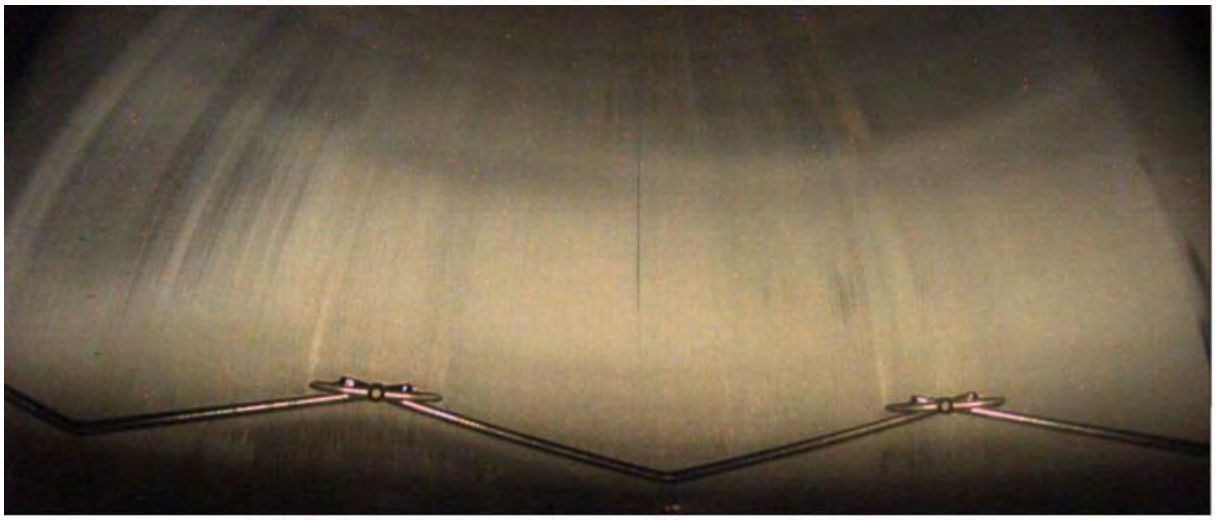
Pictures from the current inspection

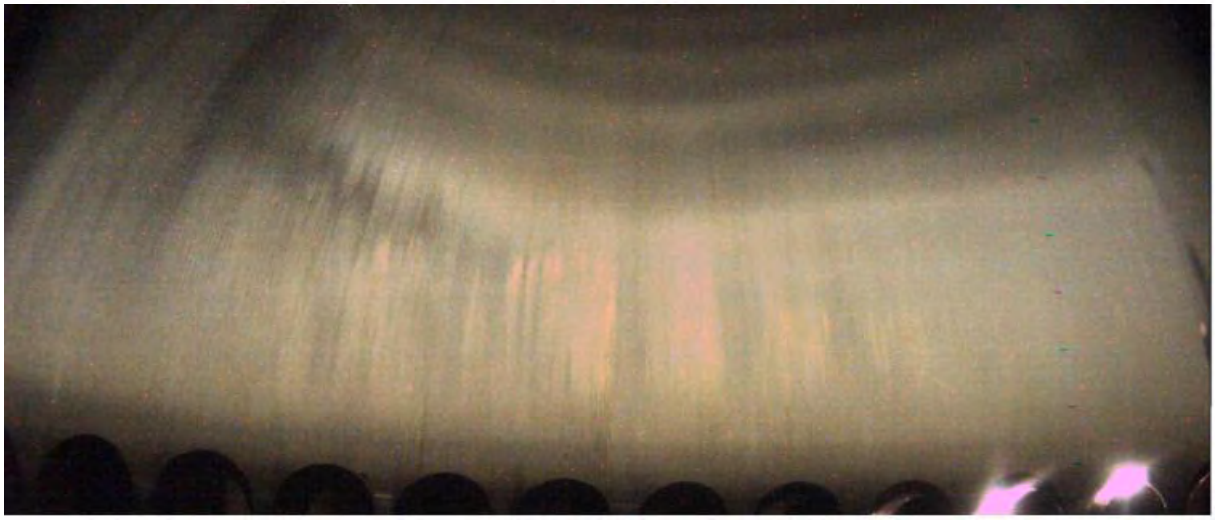
Unit #1 – Liner



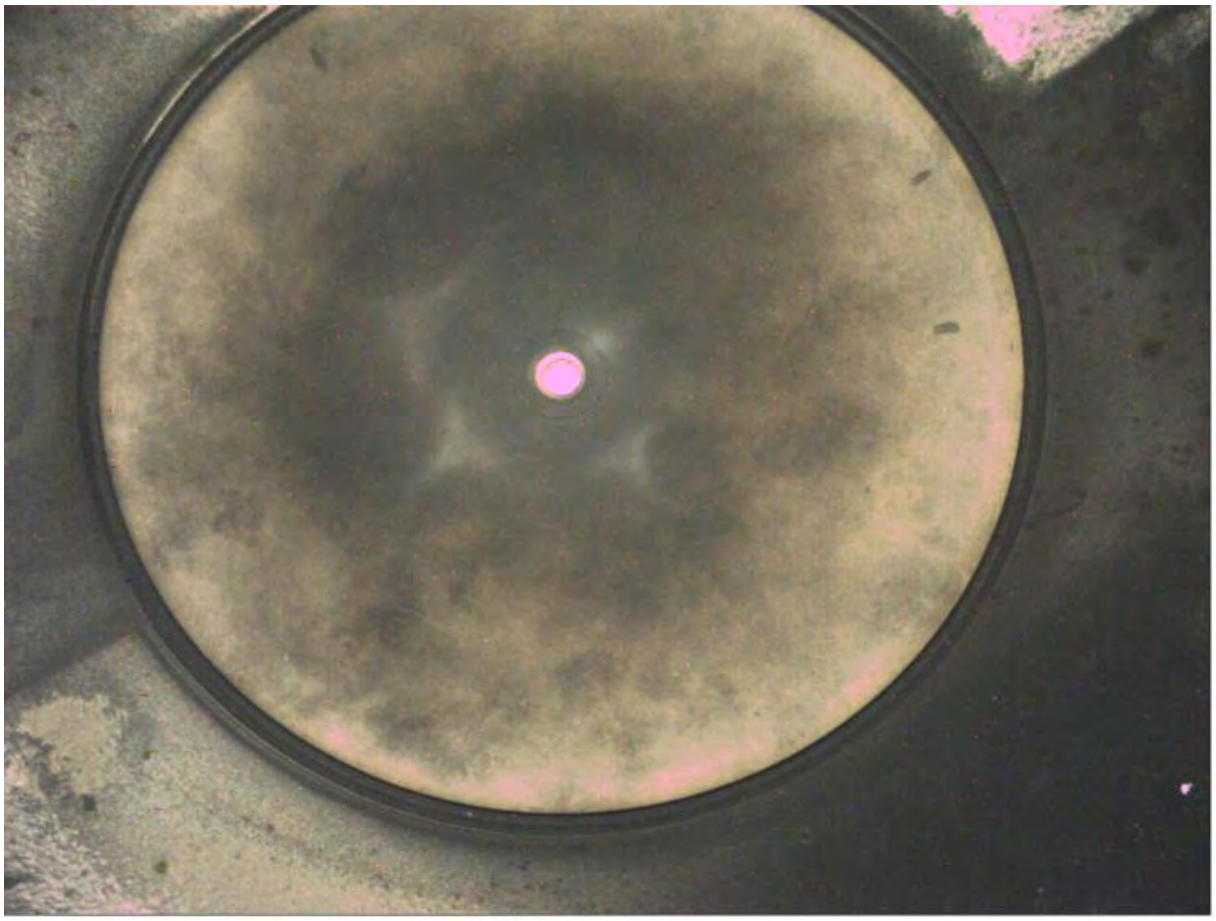
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com







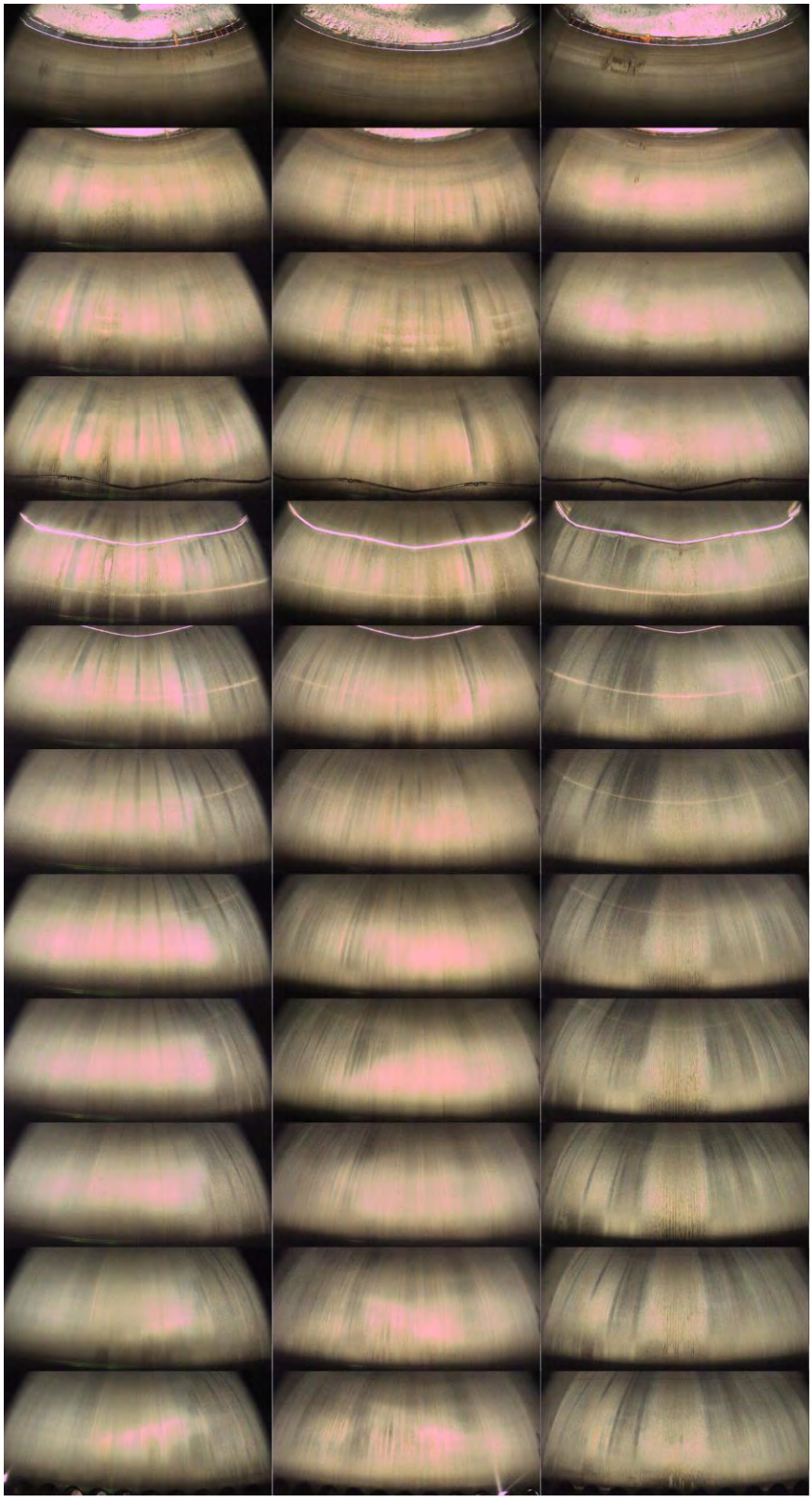
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



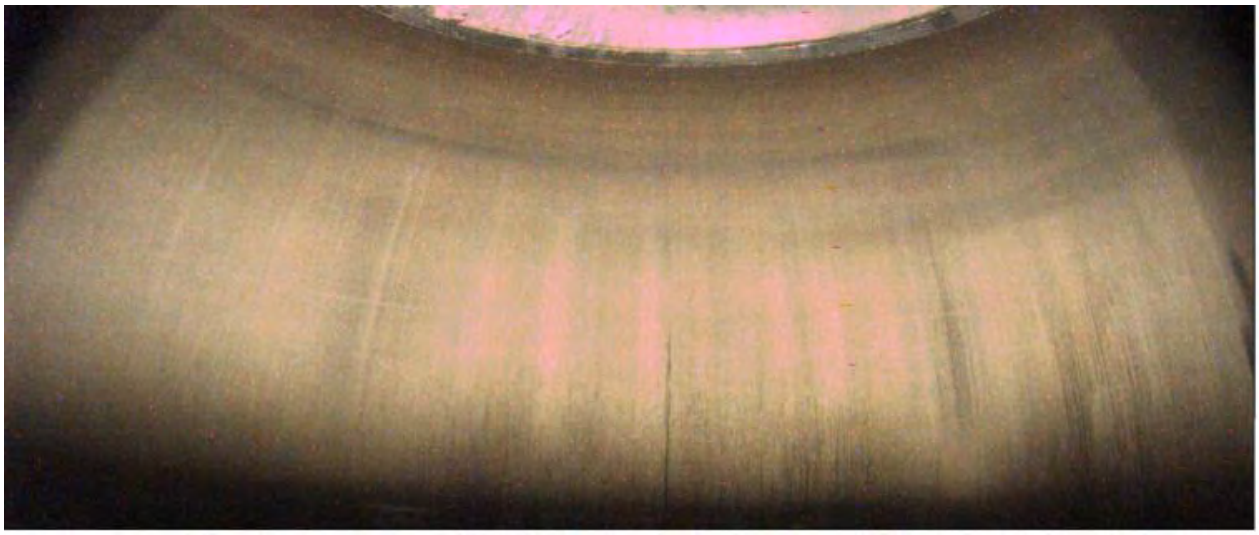
Observations: Bright liner surface in good condition with minor black deposits. No wave-cut visible. Exhaust valve in good condition.

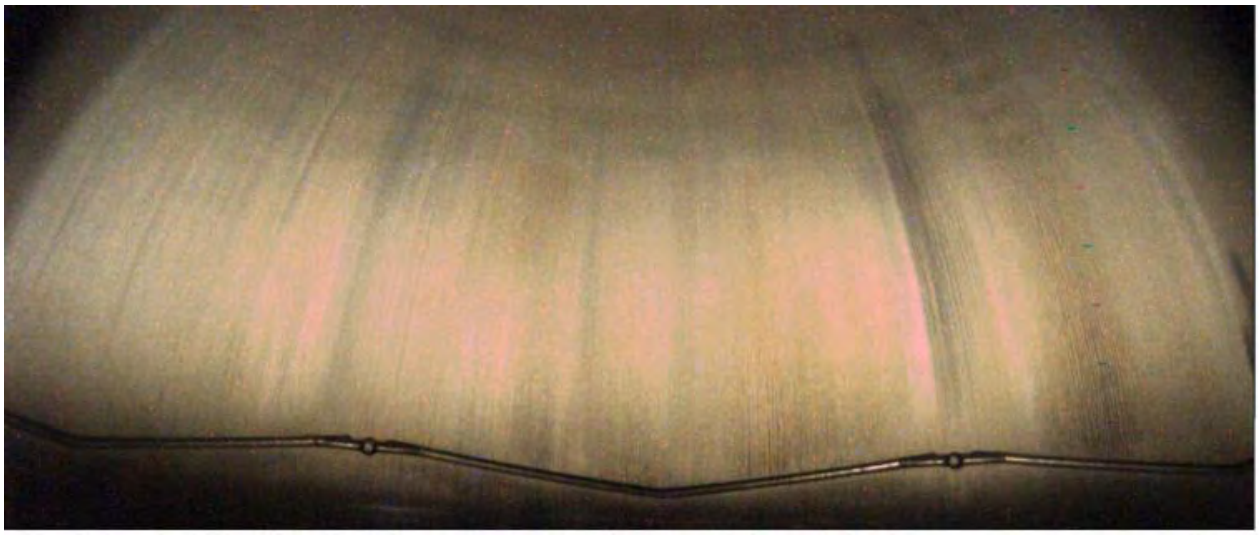
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #2 – Liner

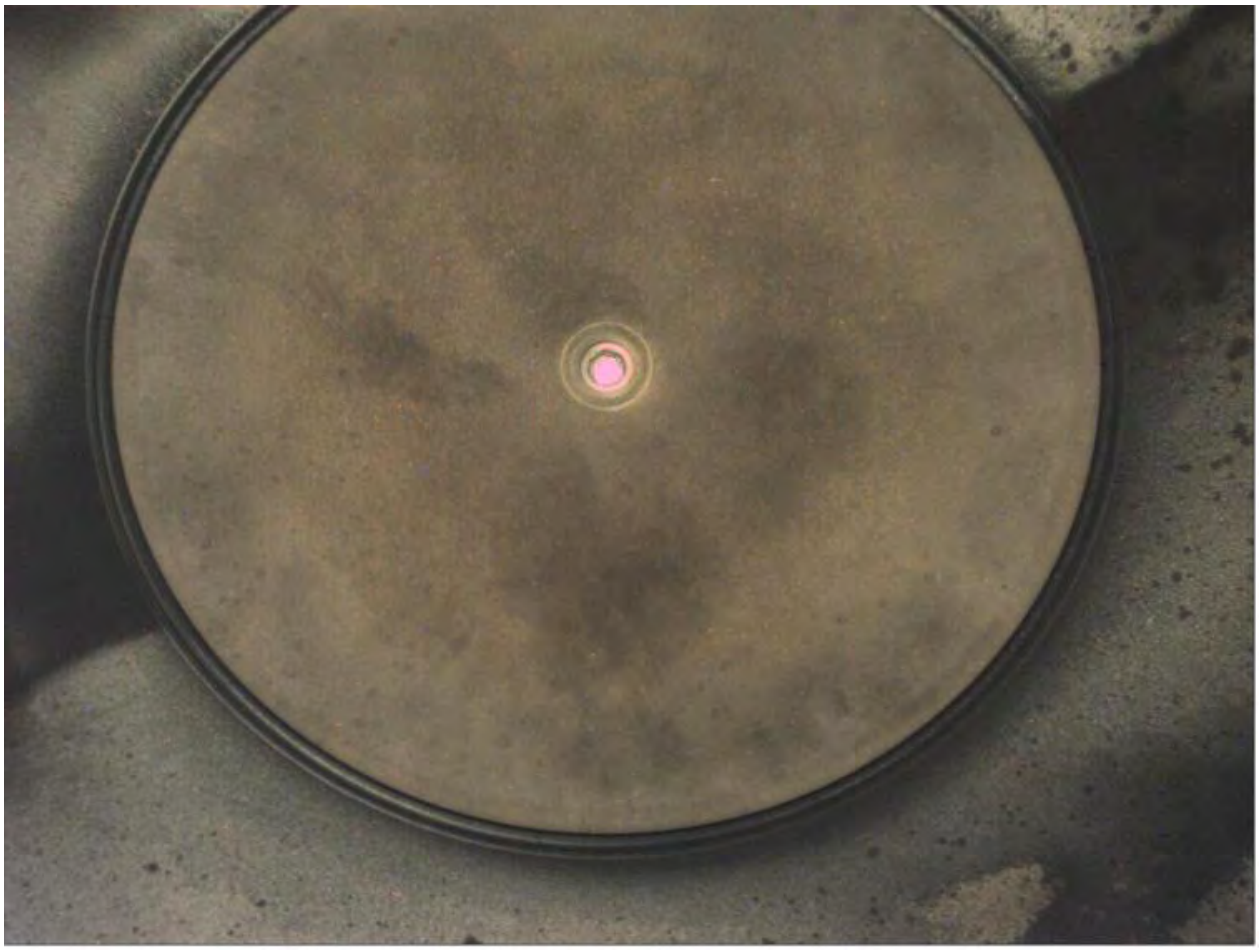


Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com





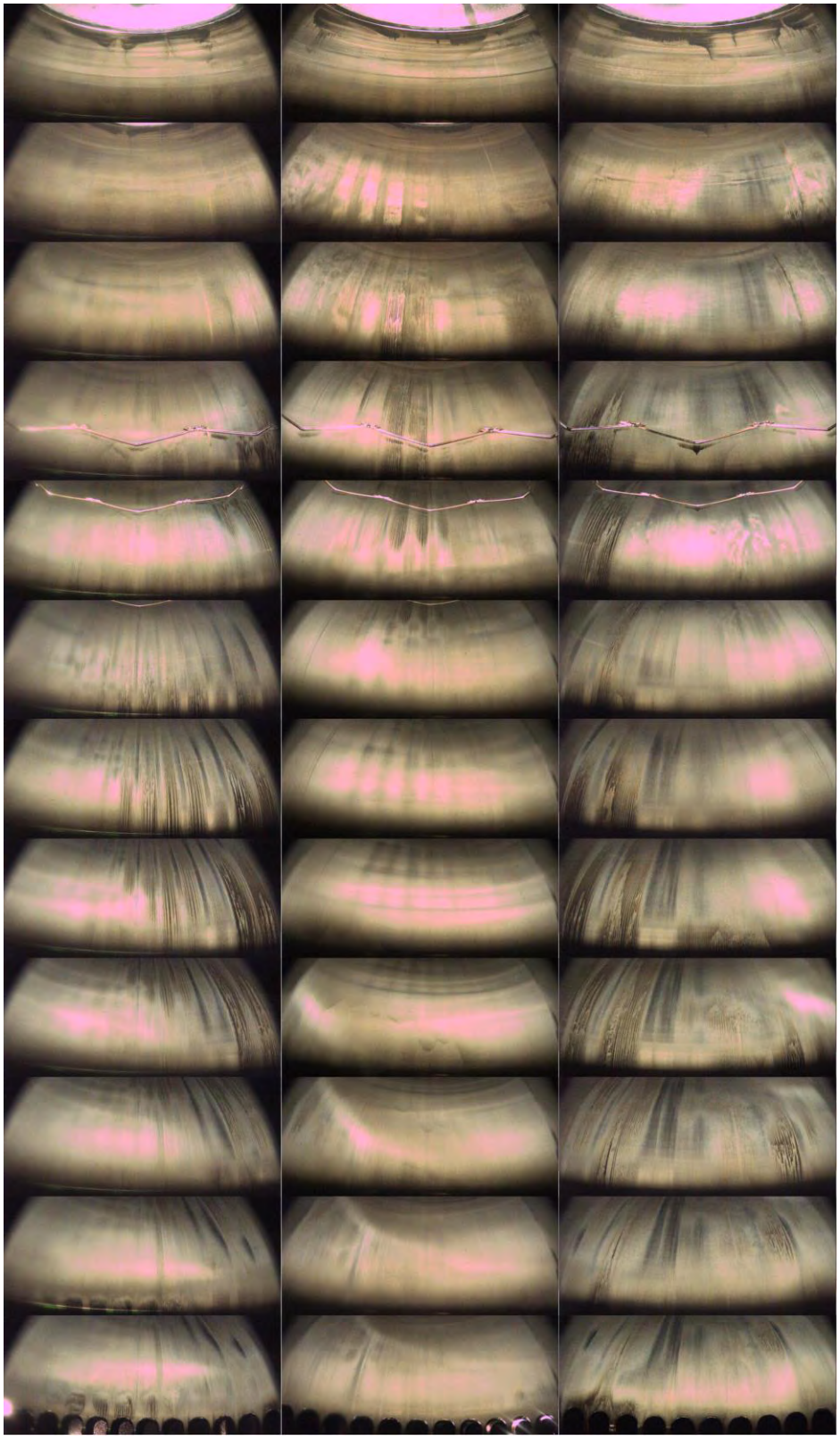
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



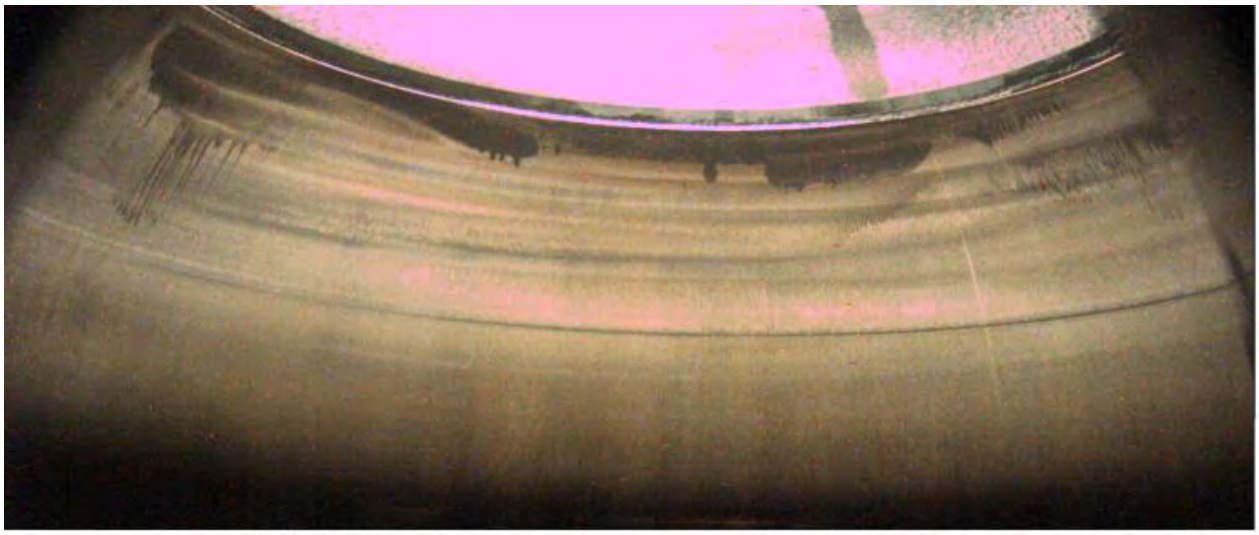
Observations: Mat liner surface in good condition with minor black deposits. No wave-cut visible. Exhaust valve in good condition.

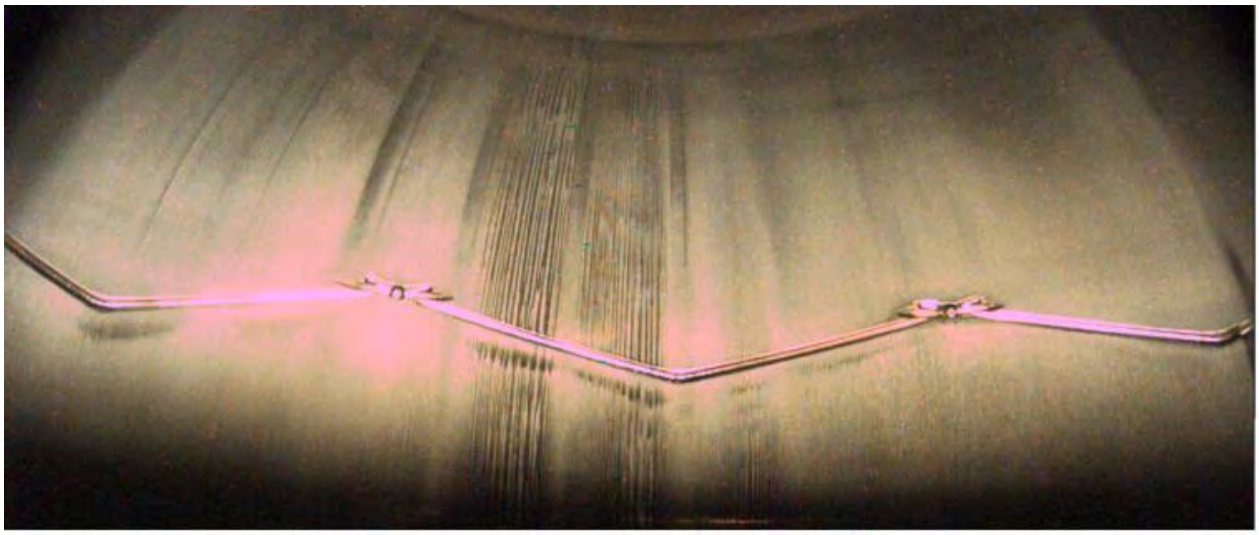
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #3 – Liner

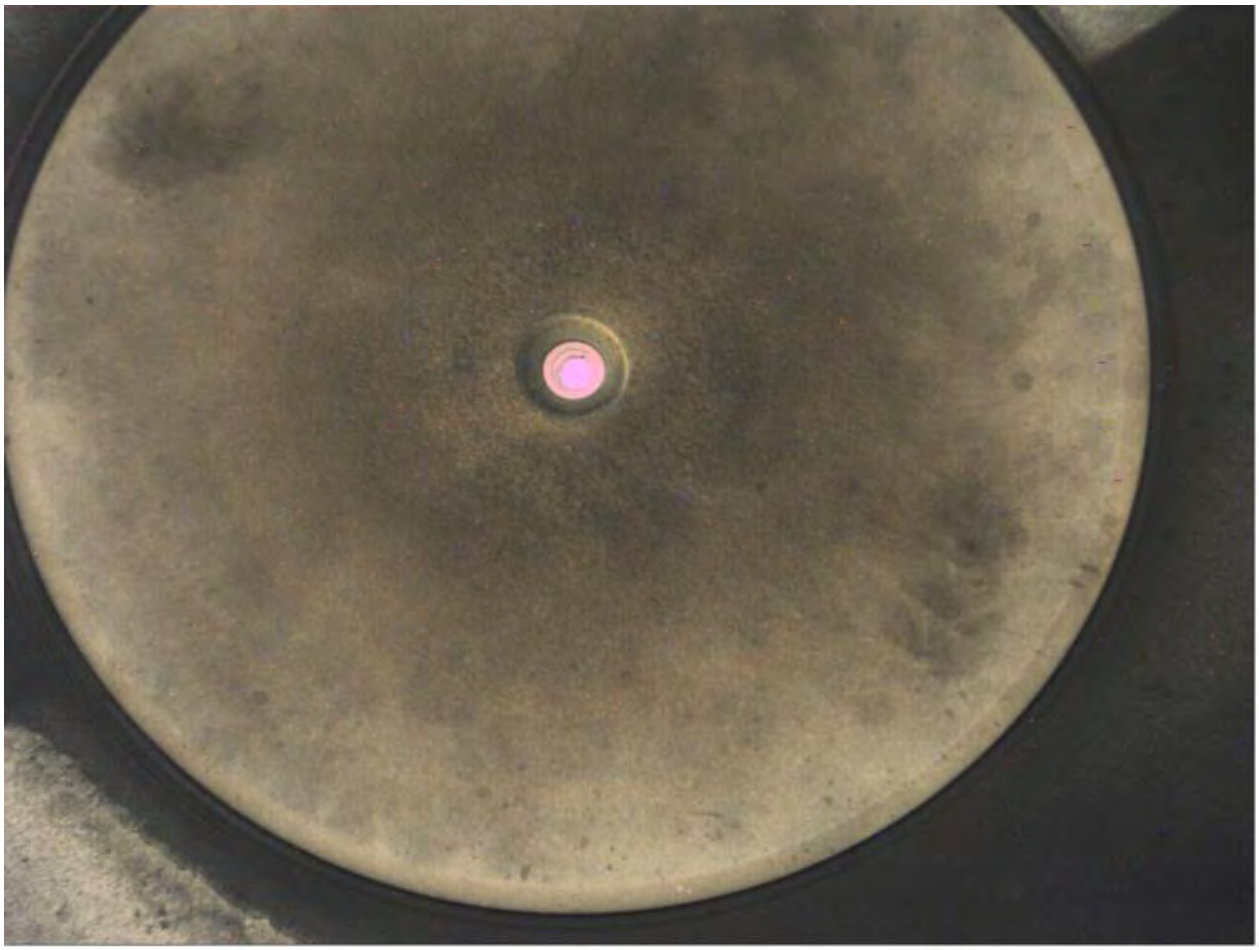


Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com





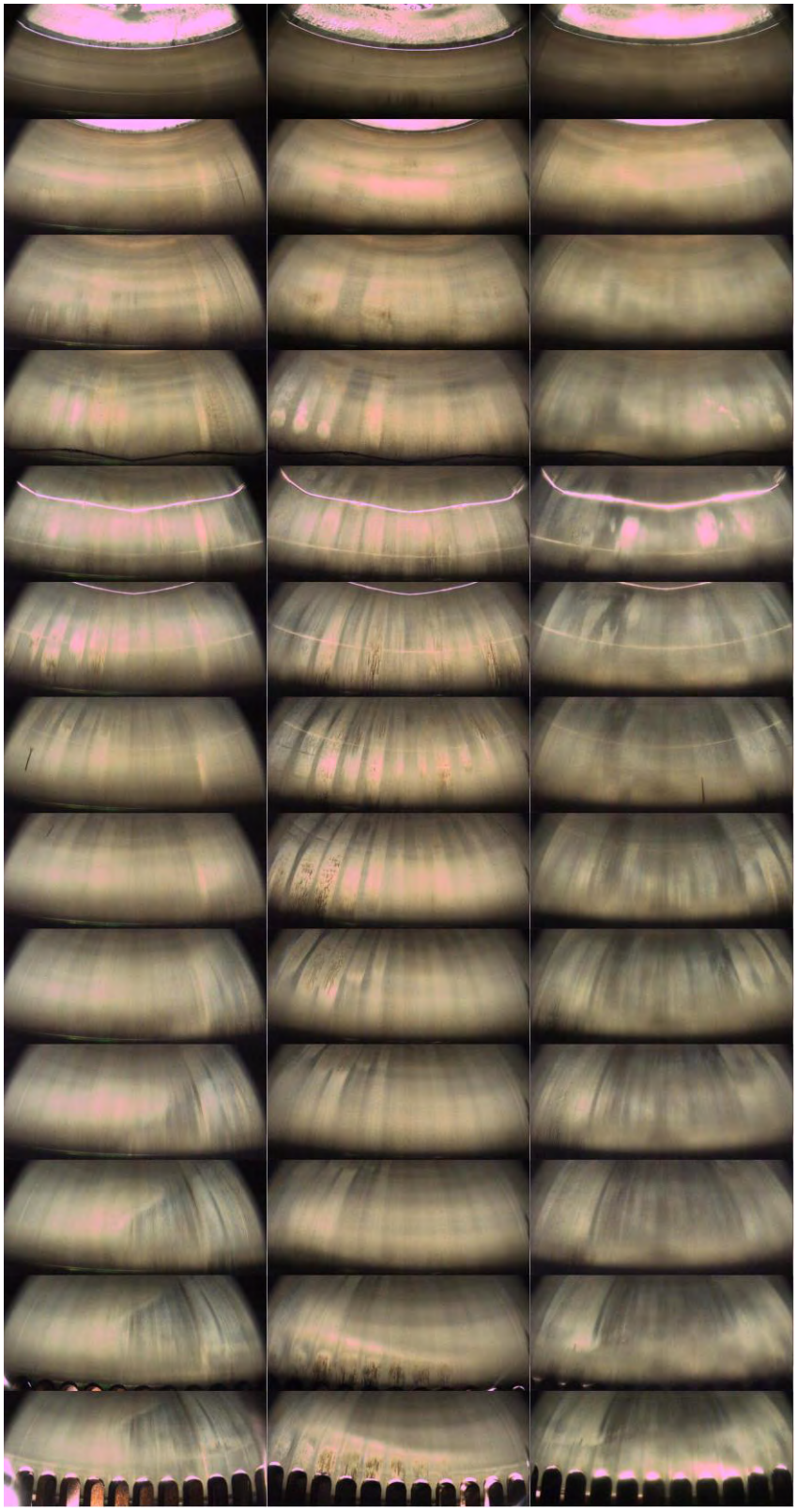
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



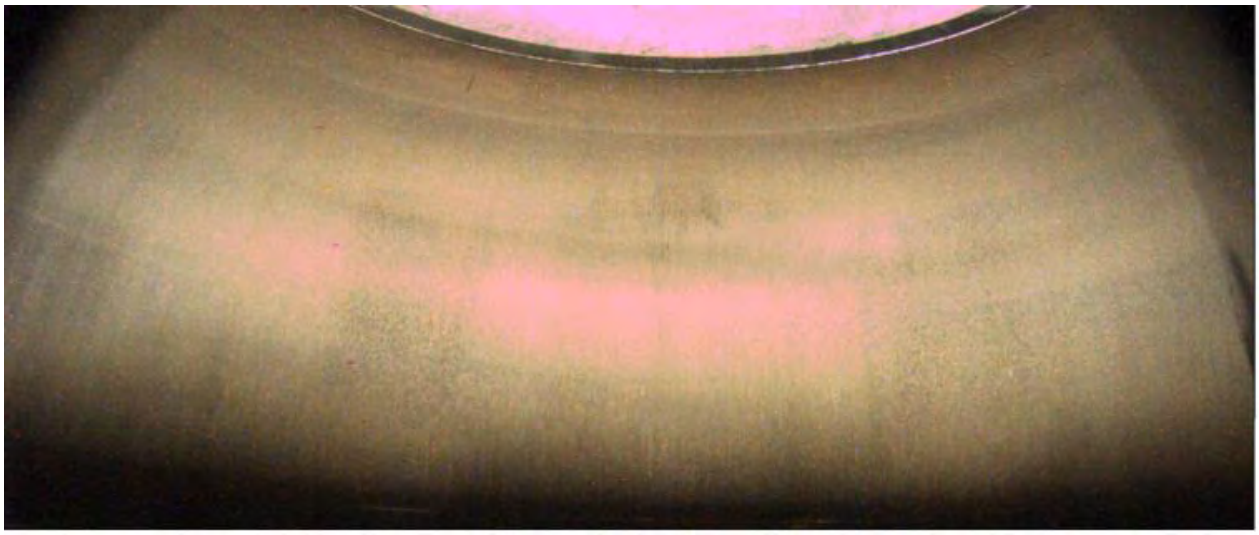
Observations: Bright liner surface in good condition with some black deposits. No wave-cut visible. Exhaust valve in good condition.

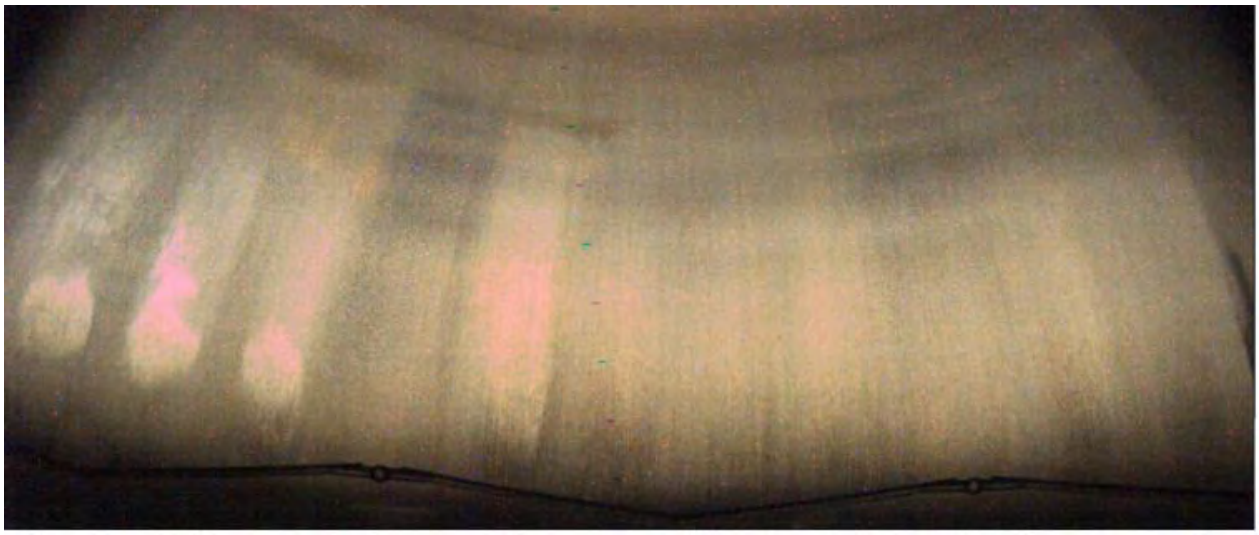
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

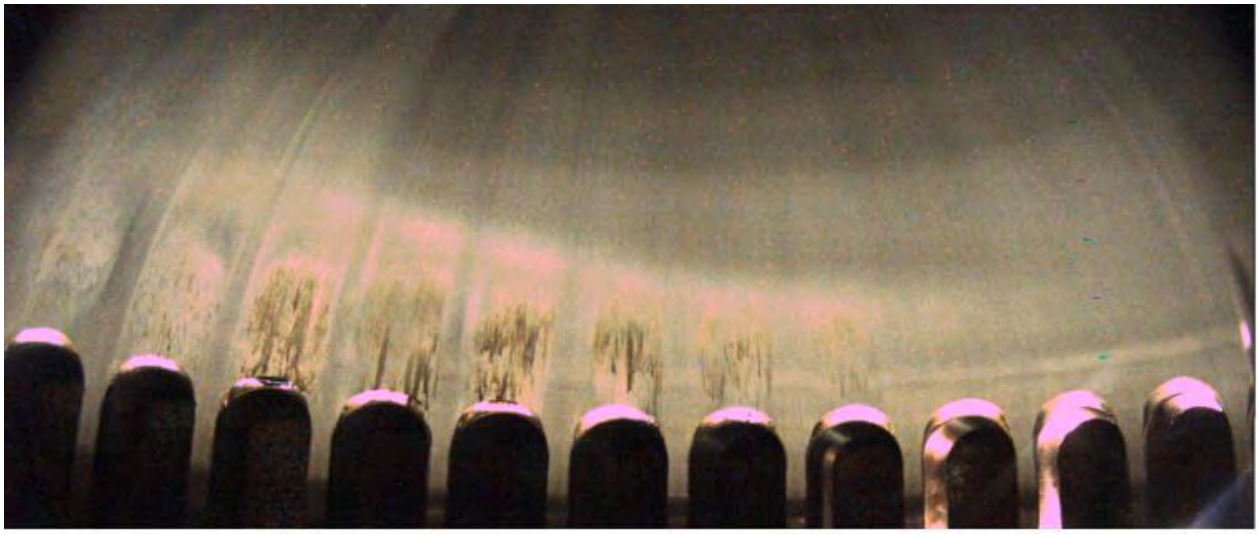
Unit #4 – Liner



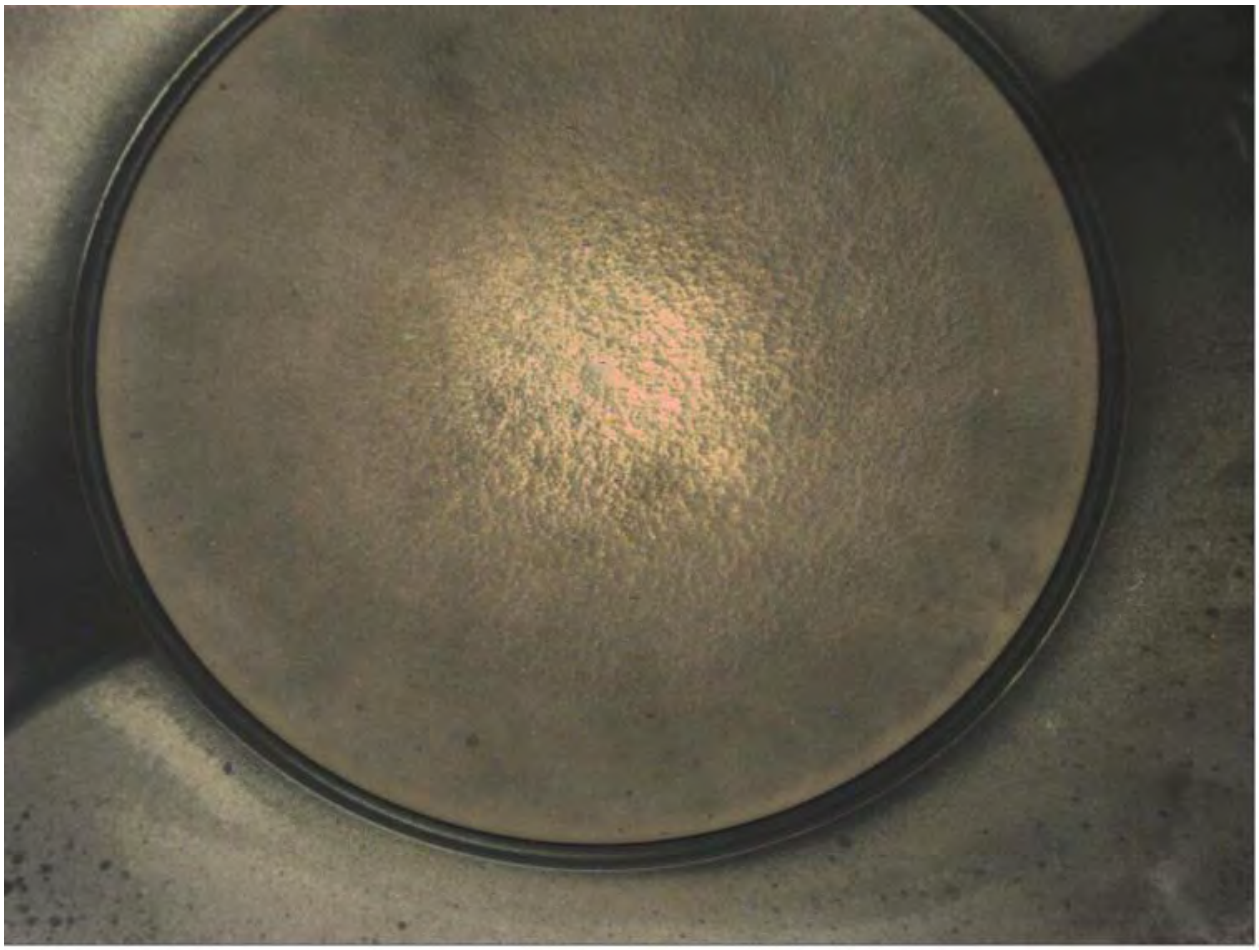
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com







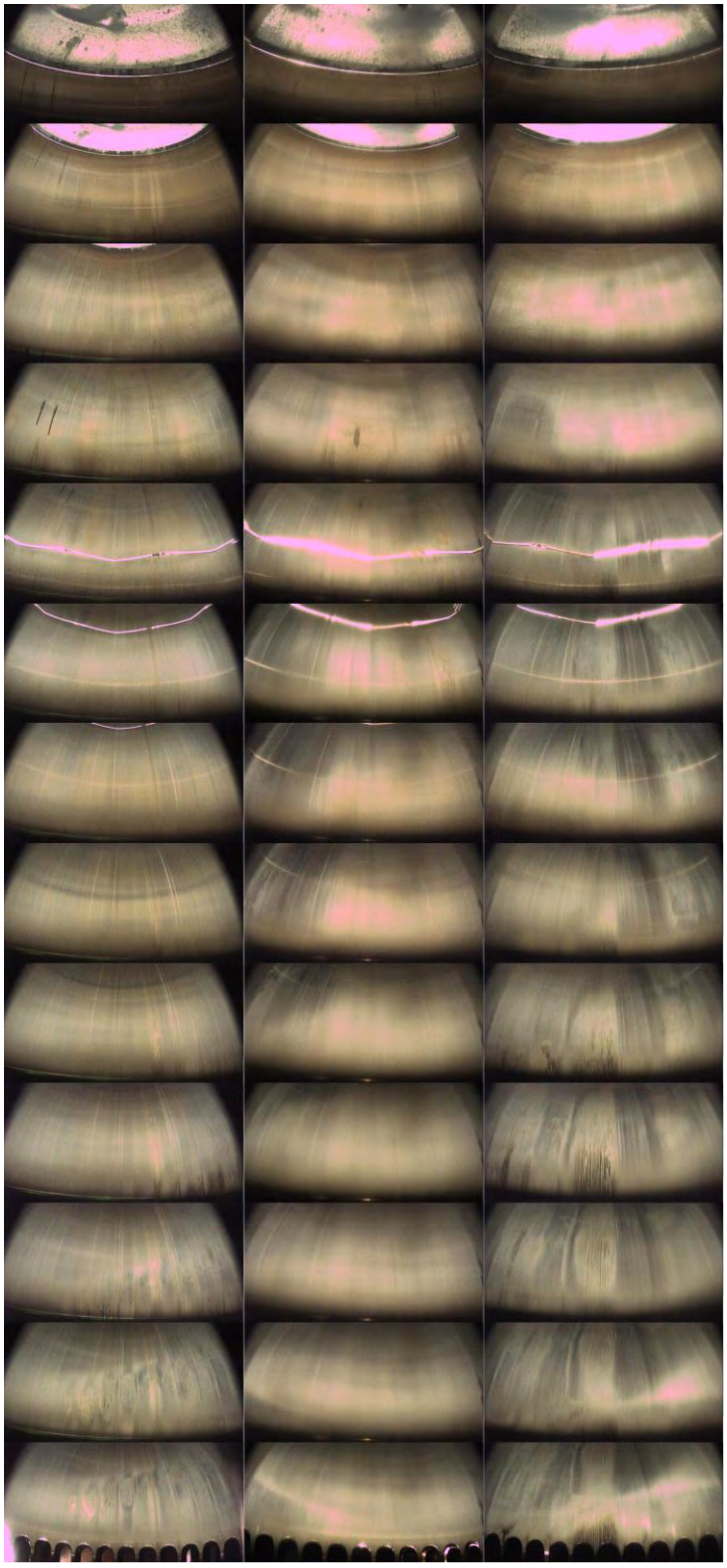
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



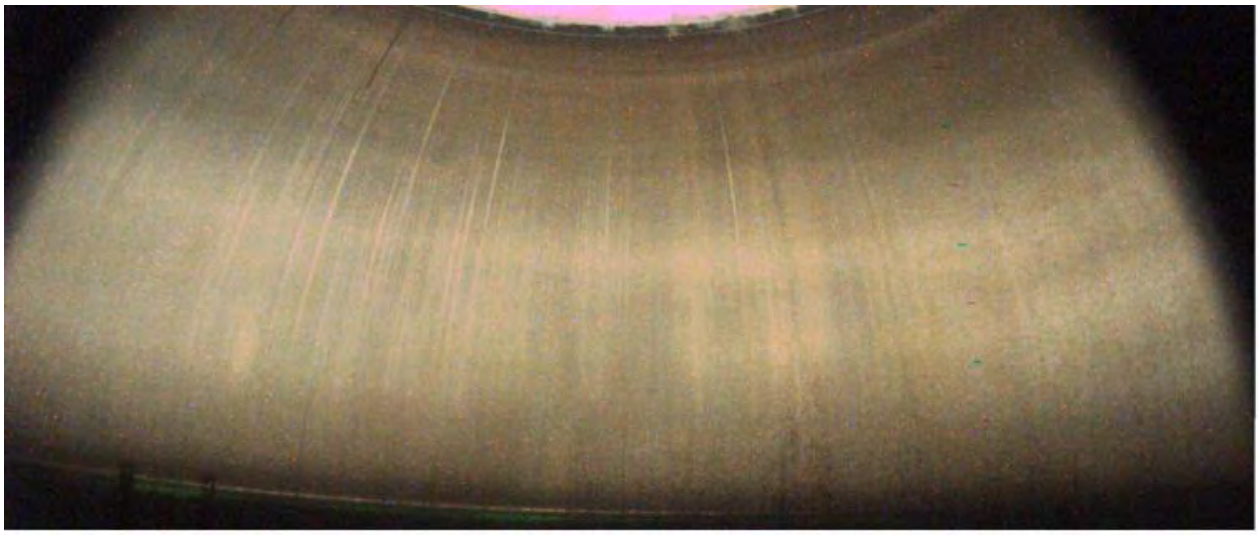
Observations: Mat liner surface with some black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.

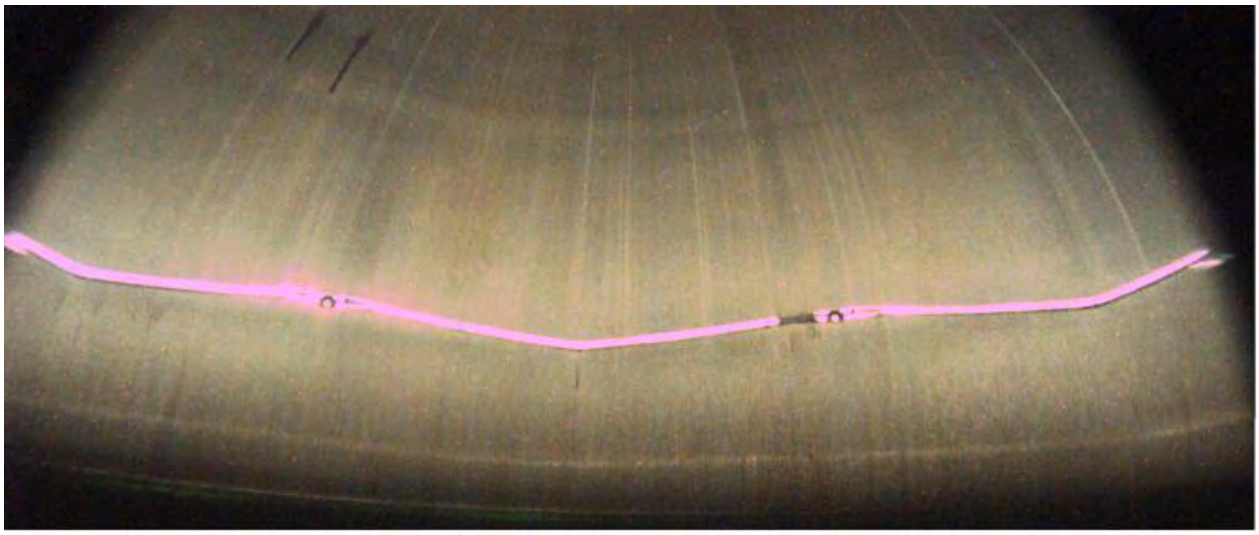
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #5 – Liner

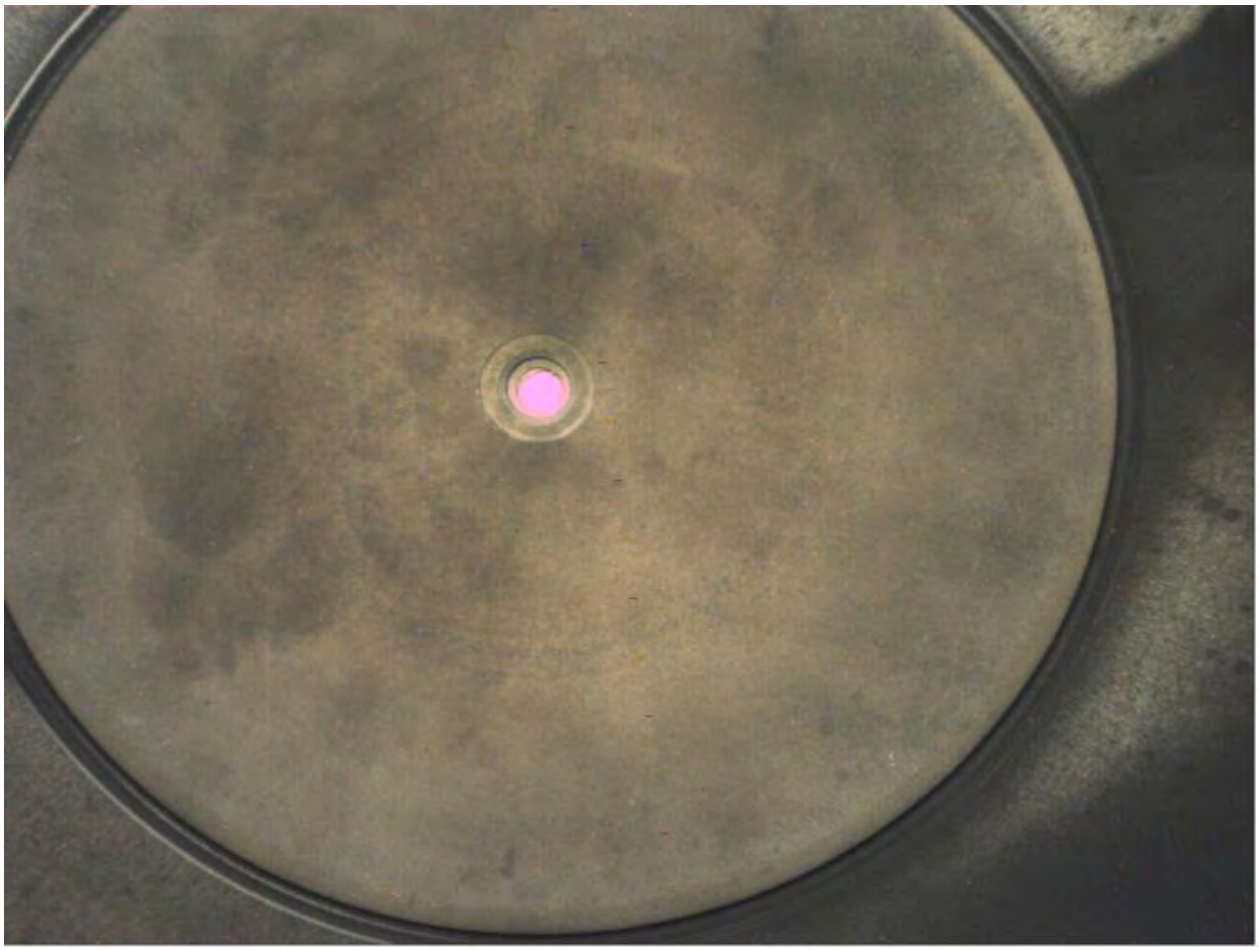


Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com





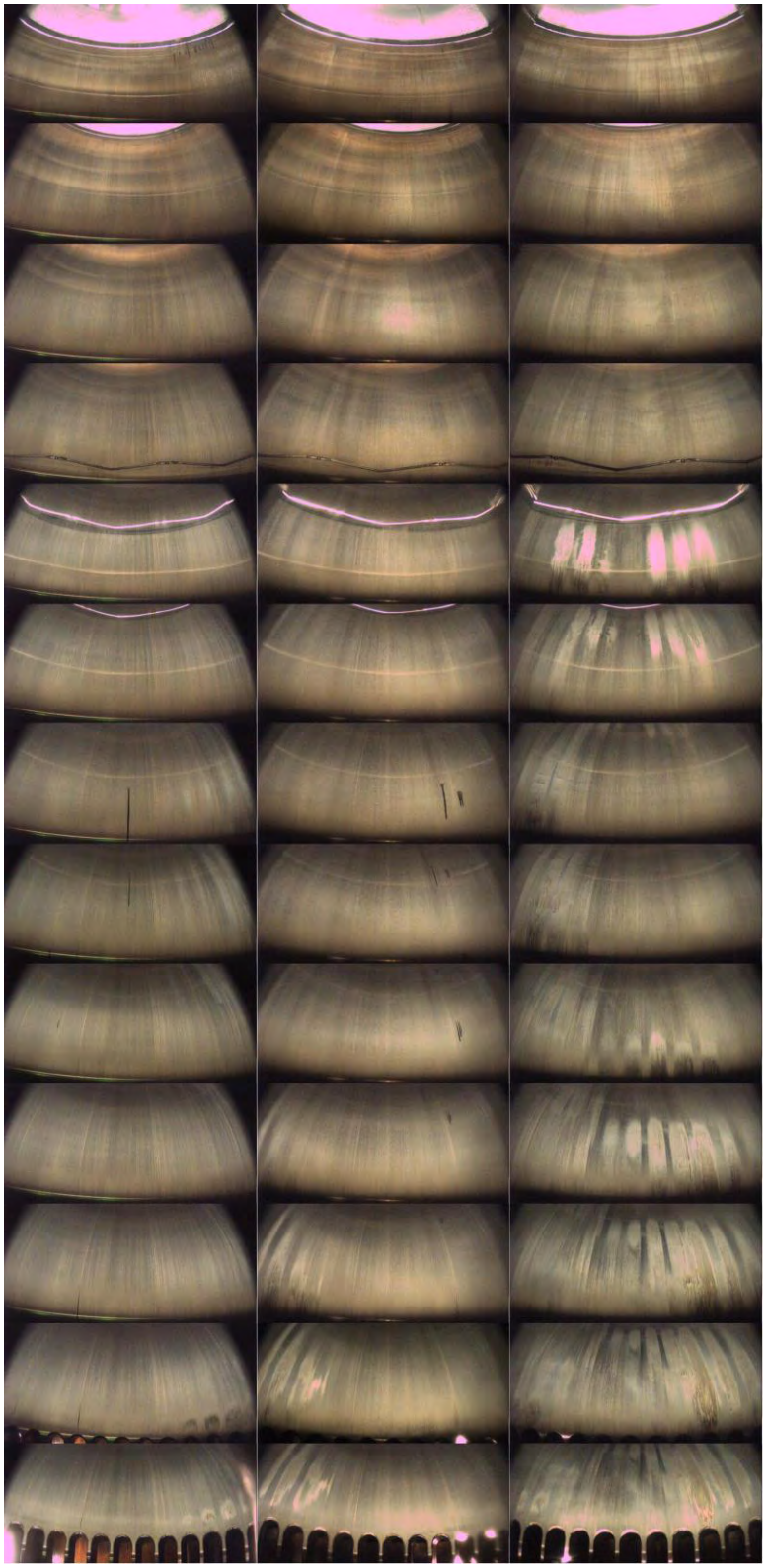
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



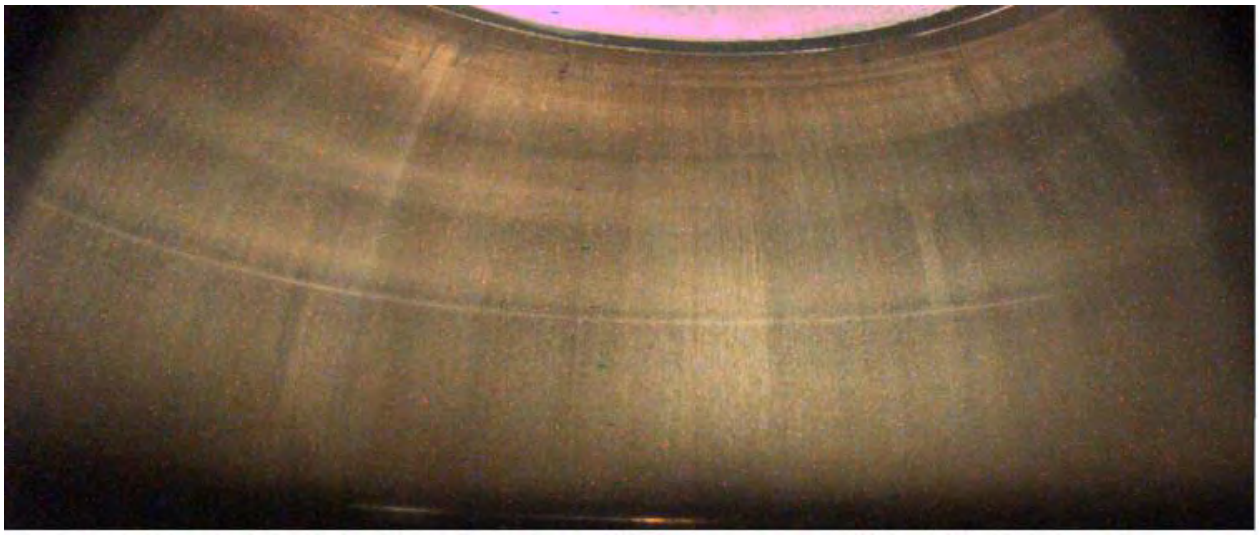
Observations: Mat liner surface with some black deposits. No wave-cut visible. Exhaust valve in good condition.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

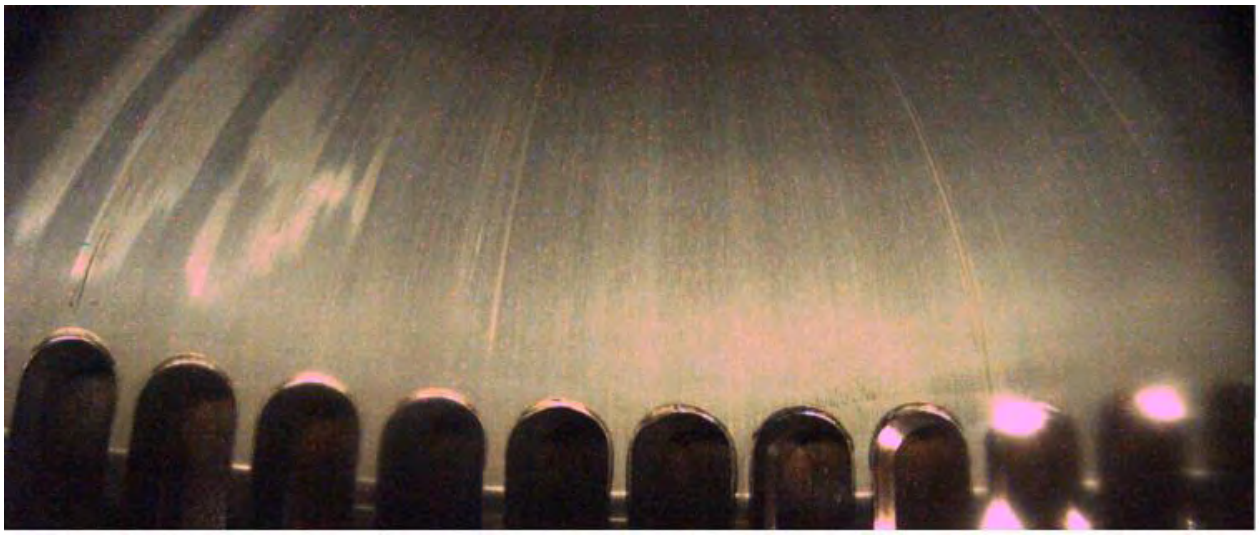
Unit #6 – Liner

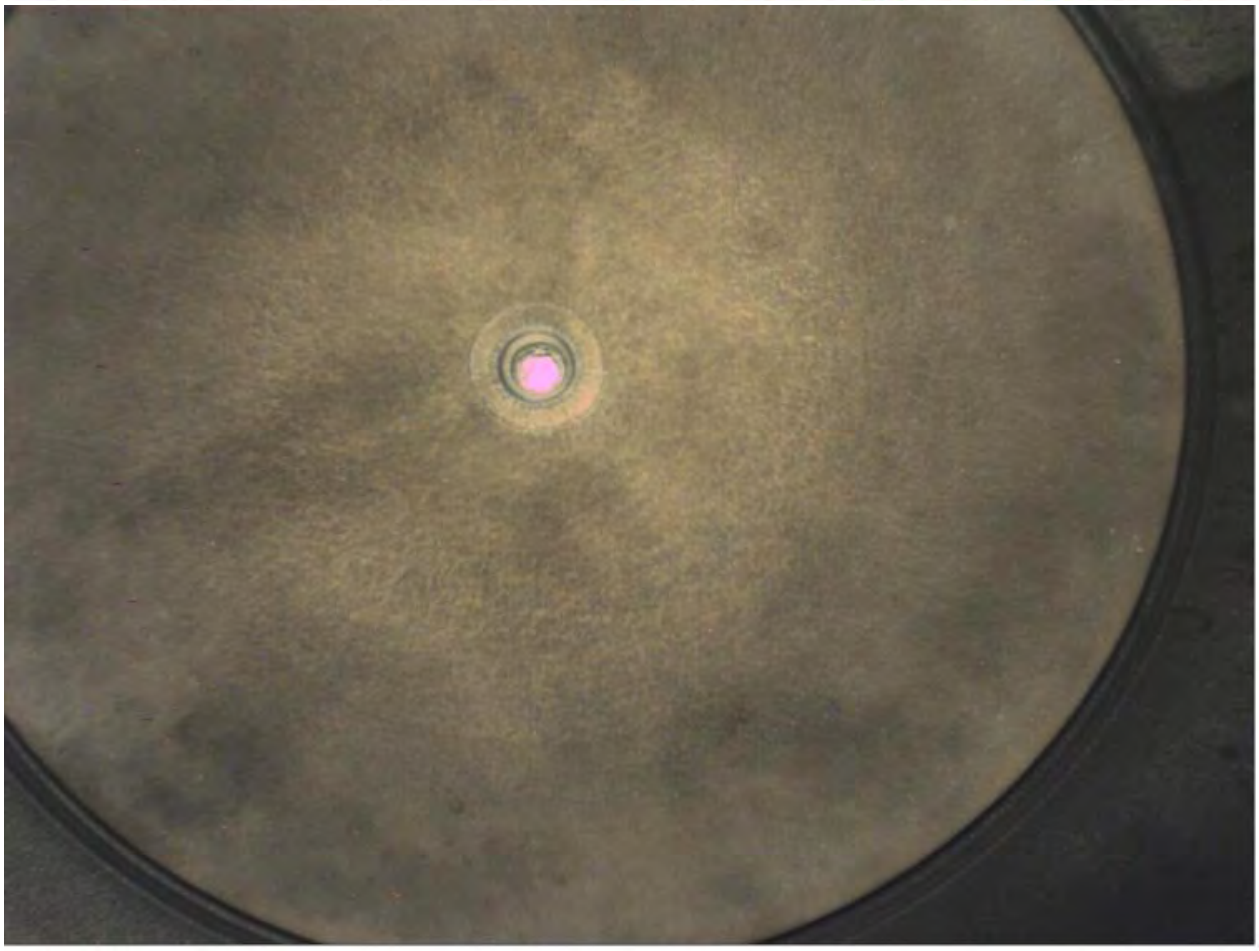


Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

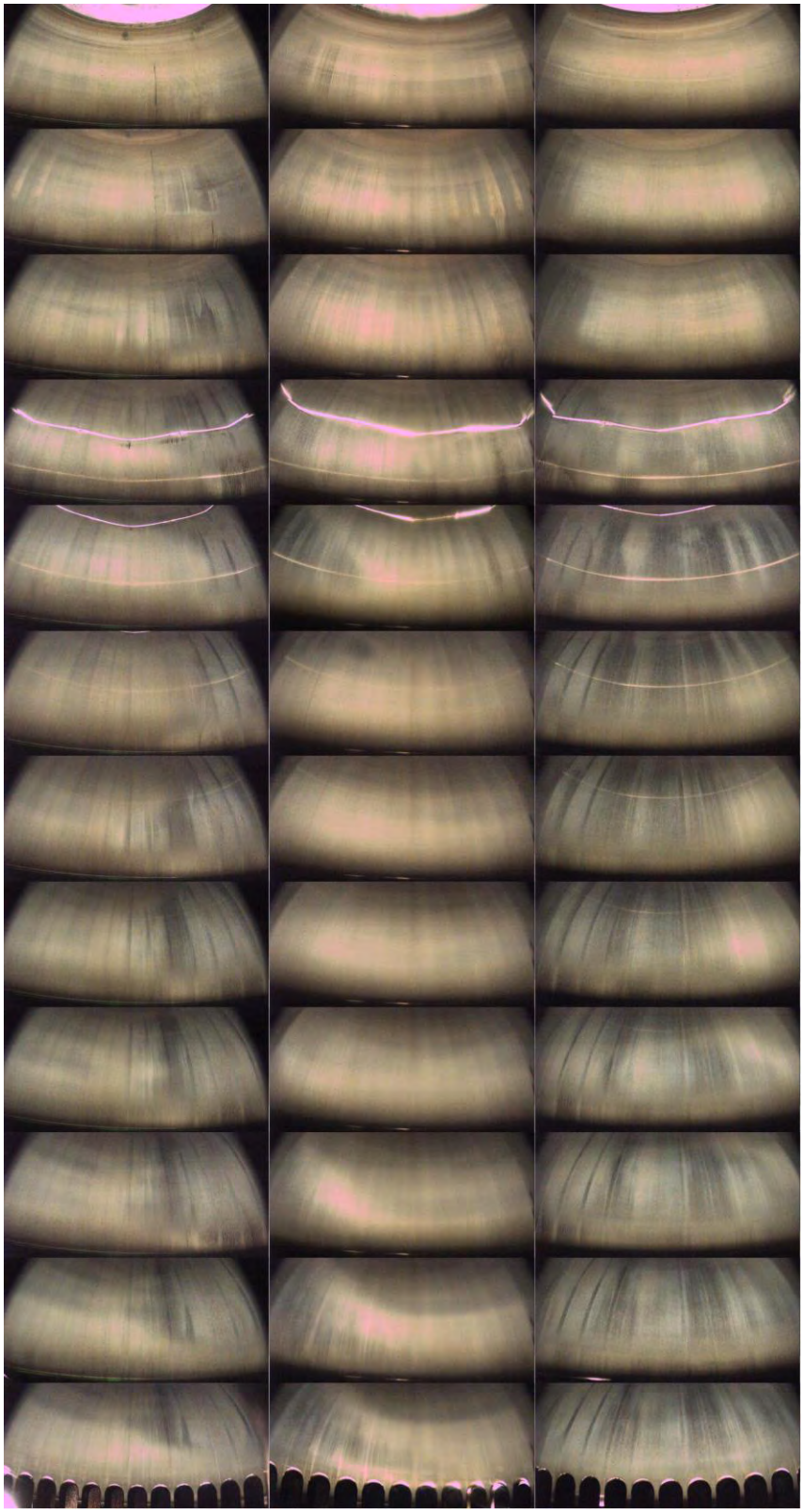




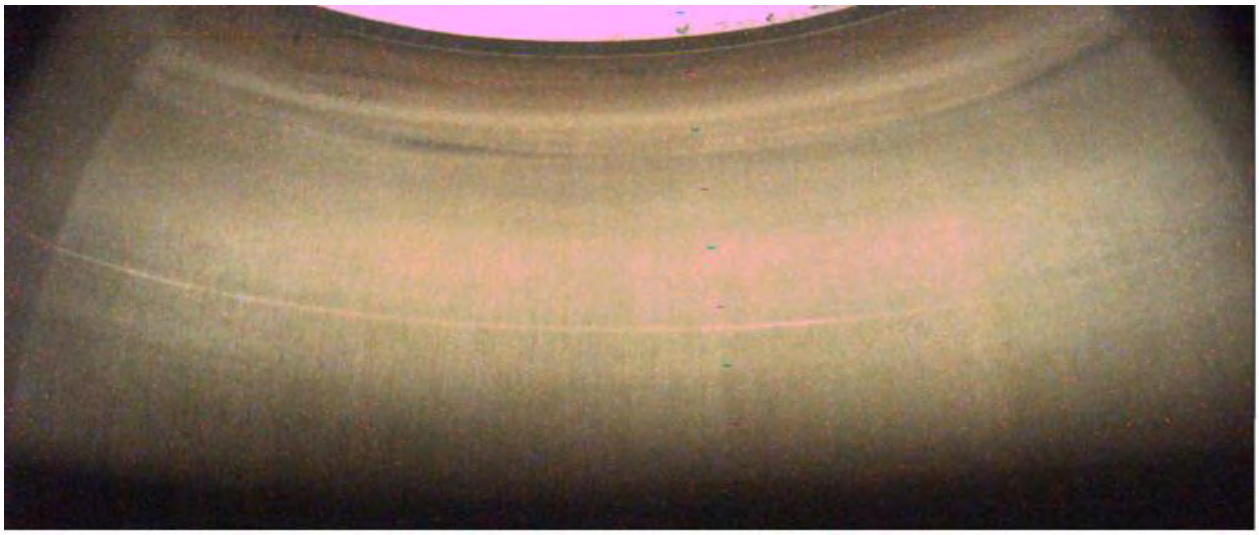
Observations: Mat liner surface with some black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.

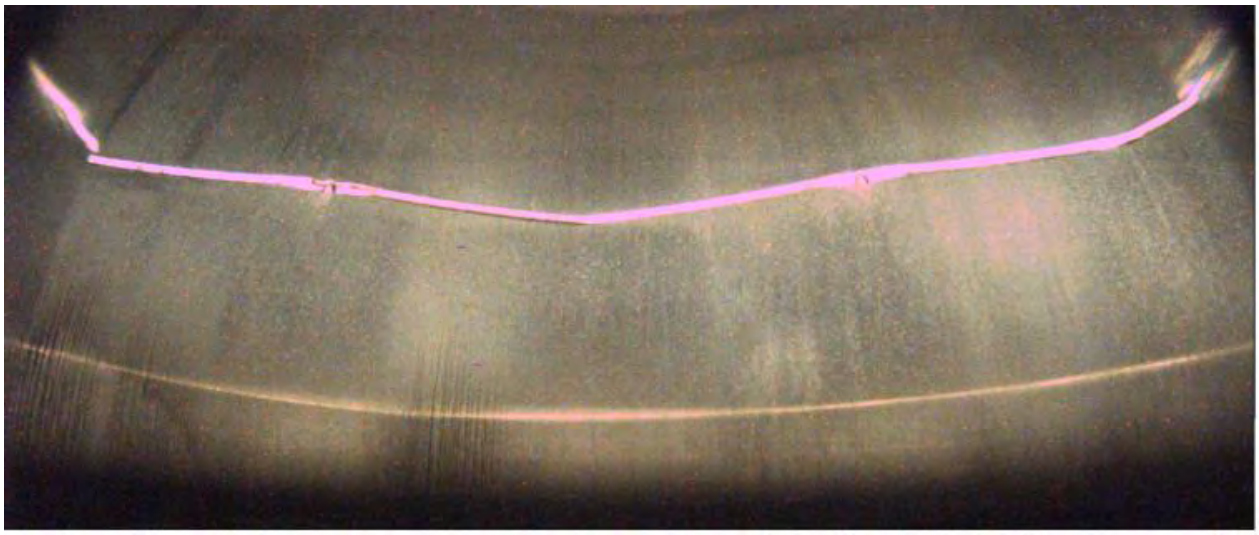
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

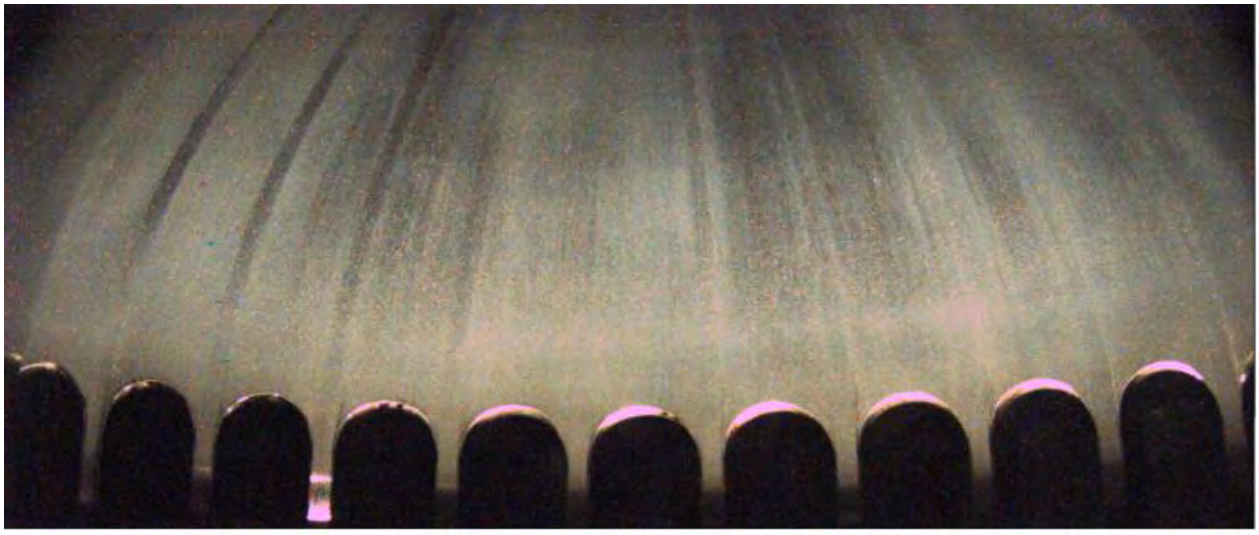
Unit #7 – Liner



Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com





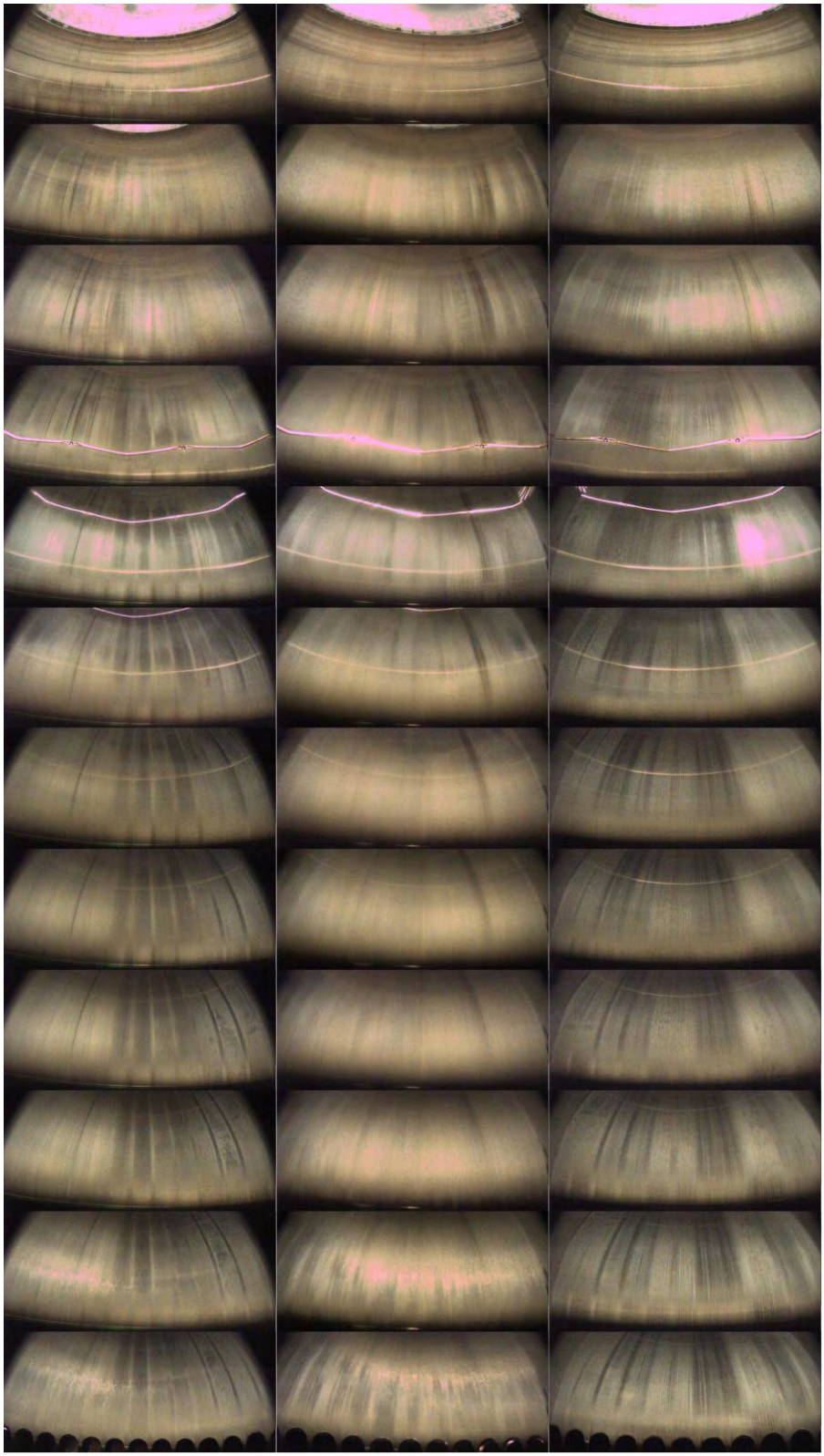


Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

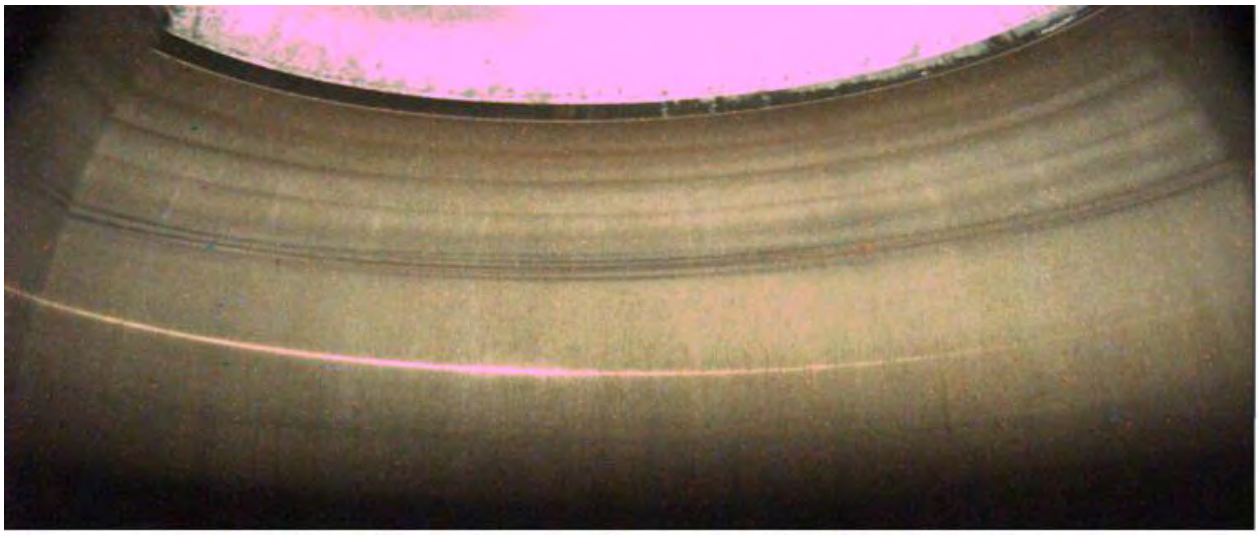
Observations: Mat liner surface with black deposits and possible scuff marks. No wave-cut visible. Exhaust valve in good condition.

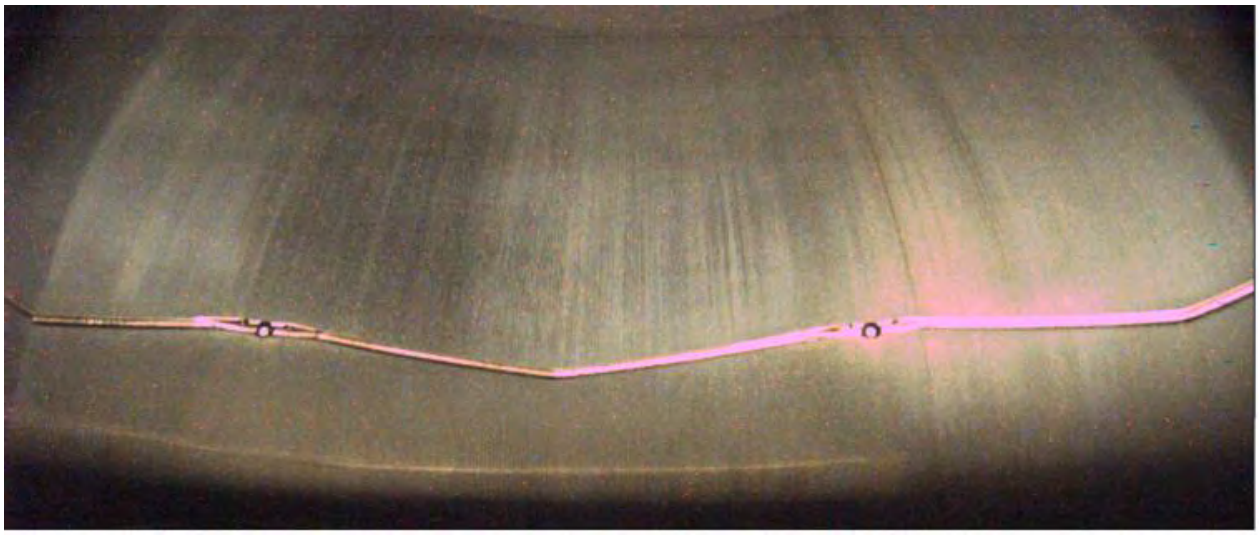
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

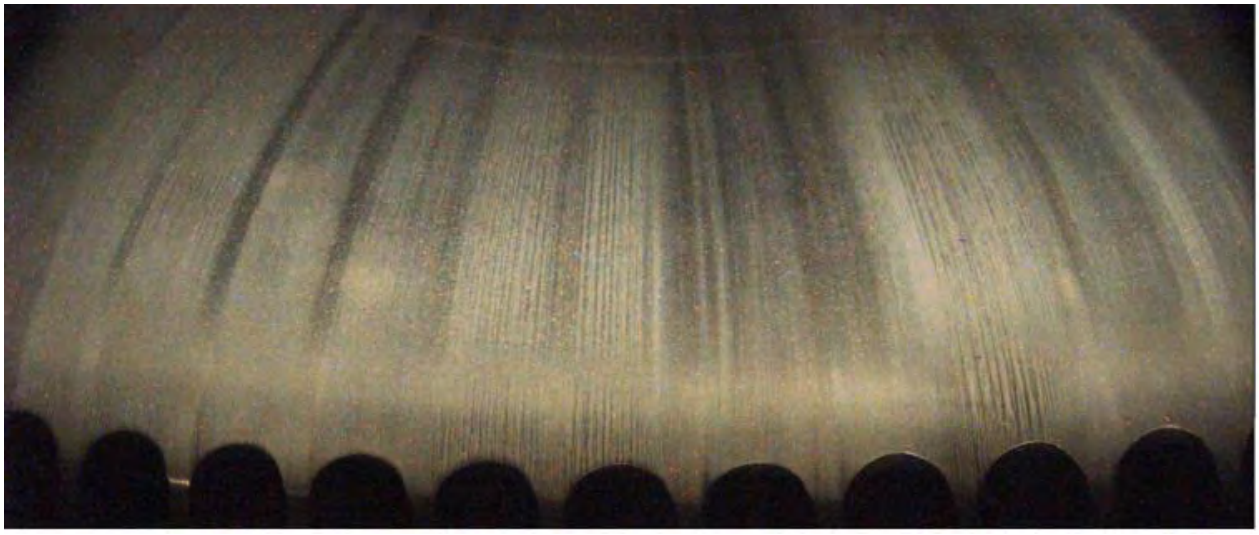
Unit #8 – Liner



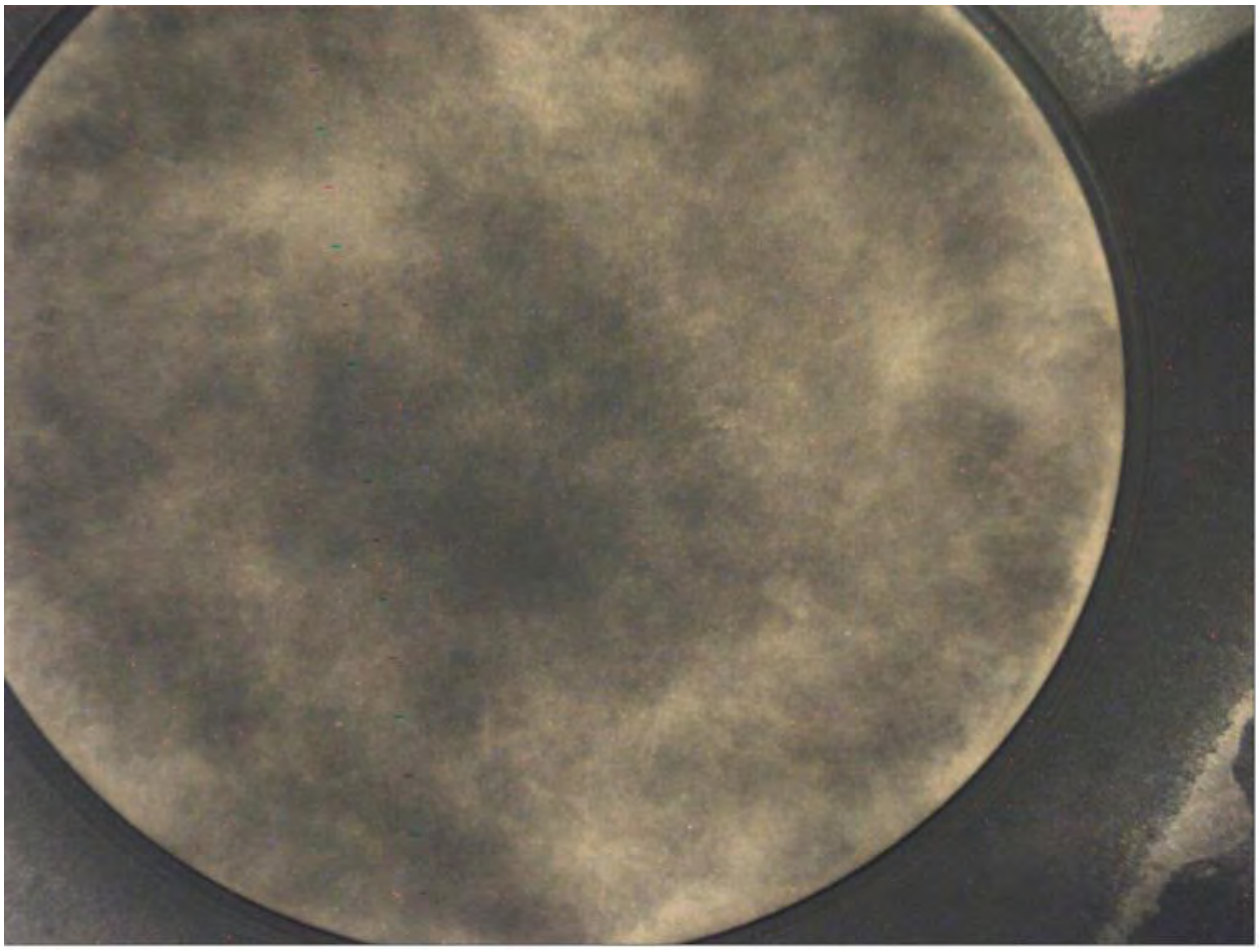
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com







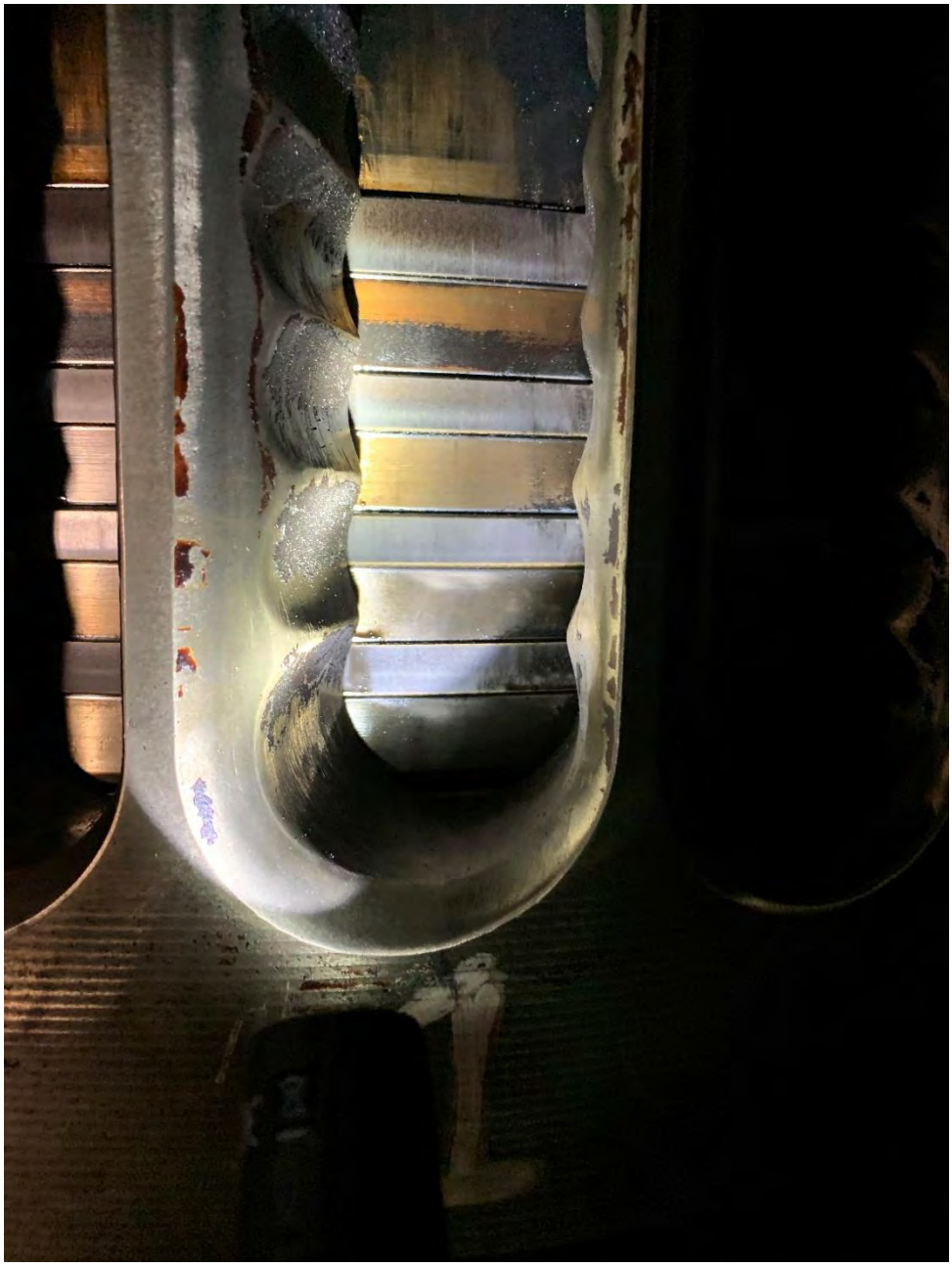
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com



Observations: Mat liner surface with black deposits. No wave-cut visible. Exhaust valve in good condition, but with some black deposits.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #1 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #2 – Piston ring pack

Observations: Ring pack in good condition. No coke deposits.

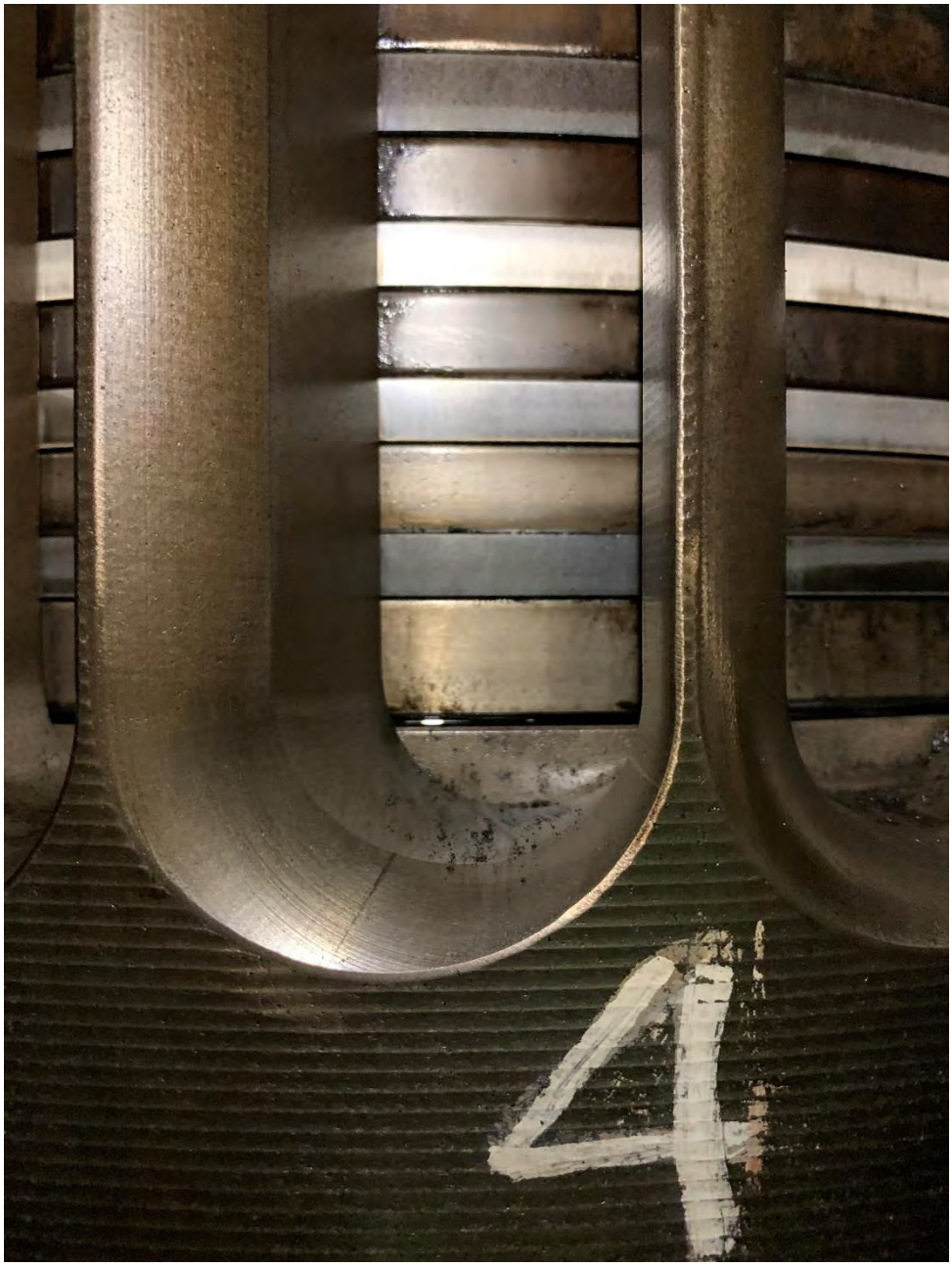
Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #3 – Piston ring pack

Observations: Ring pack in good condition. No coke deposits.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

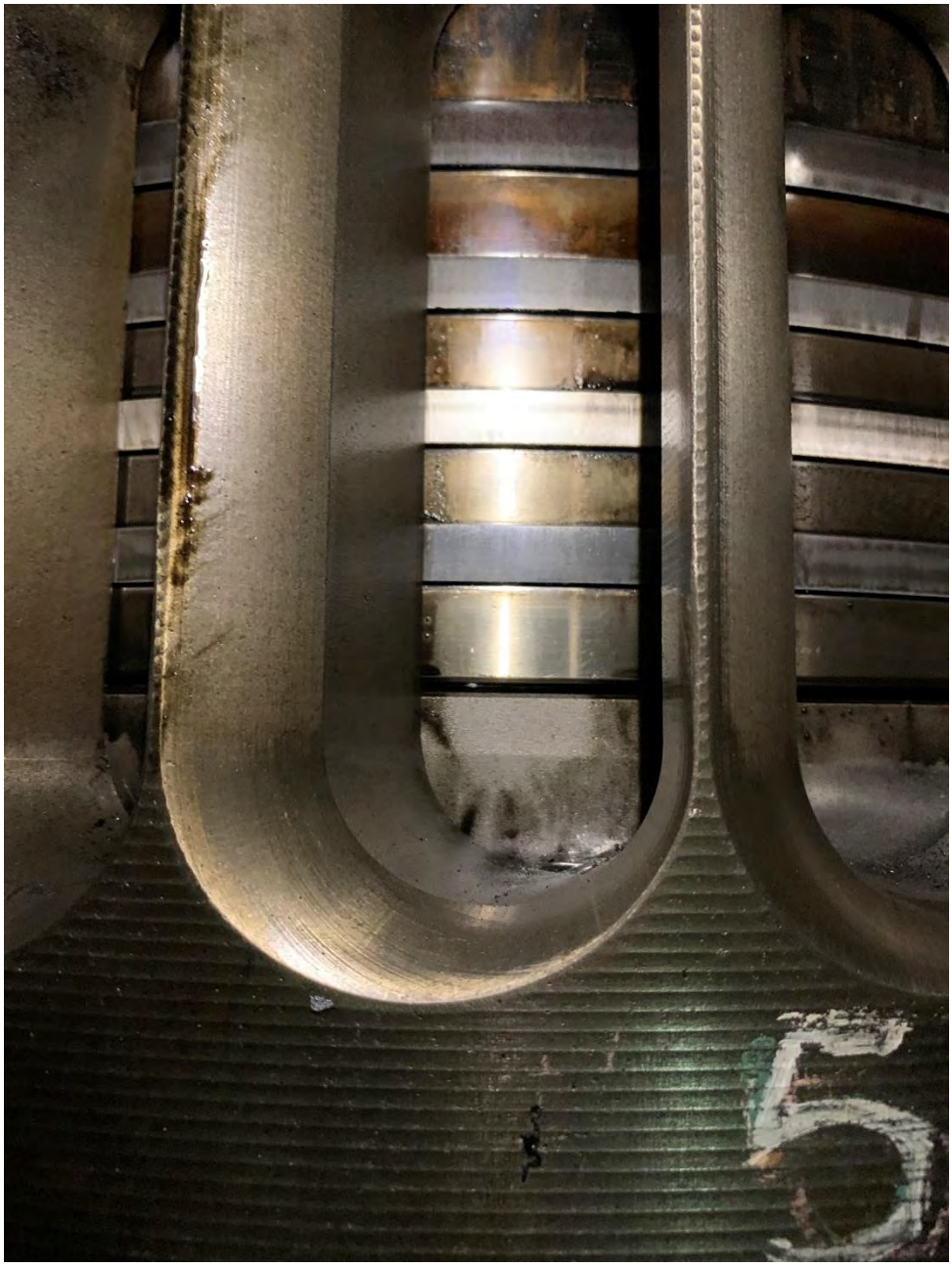
Unit #4 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

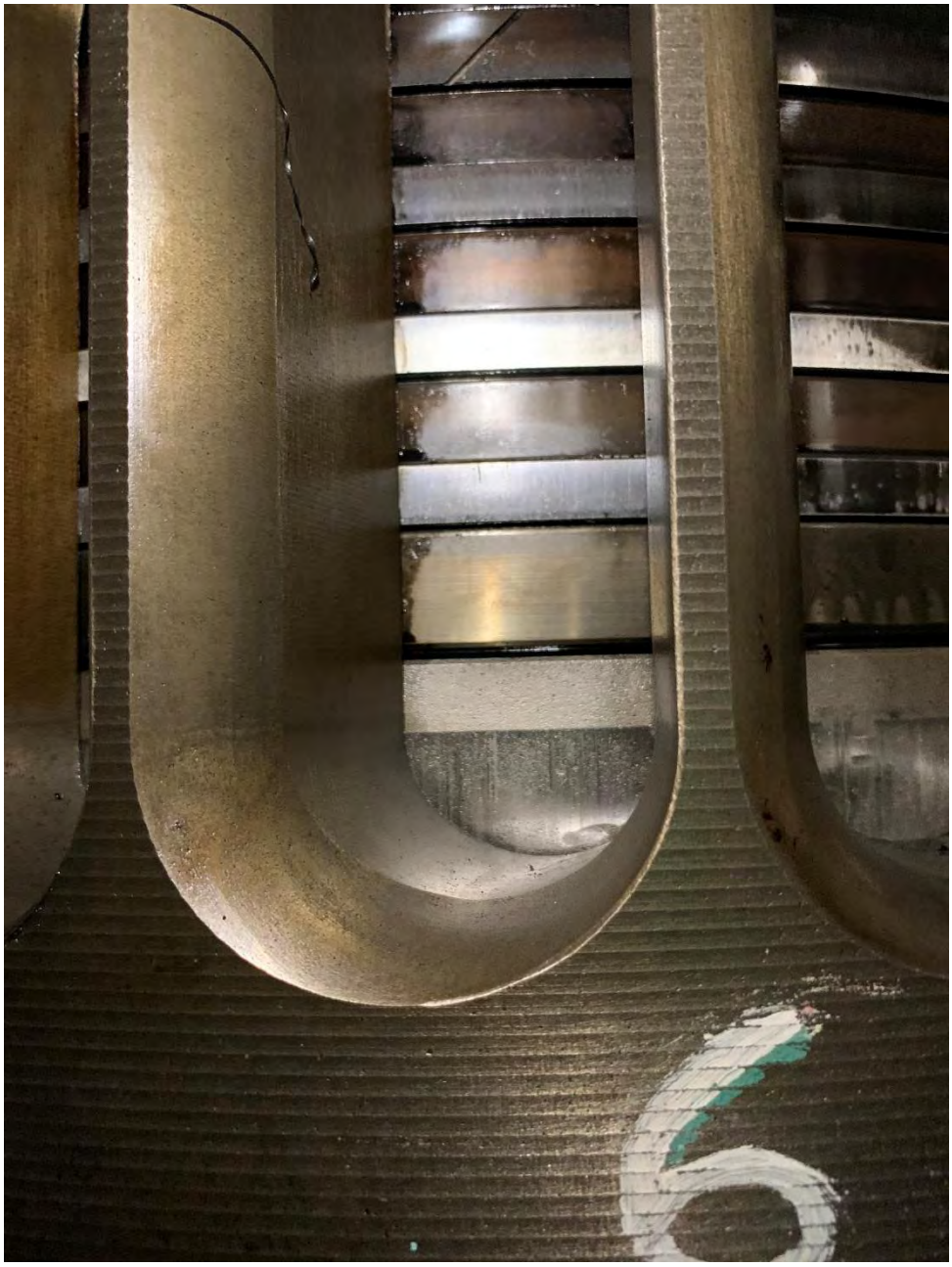
Unit #5 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

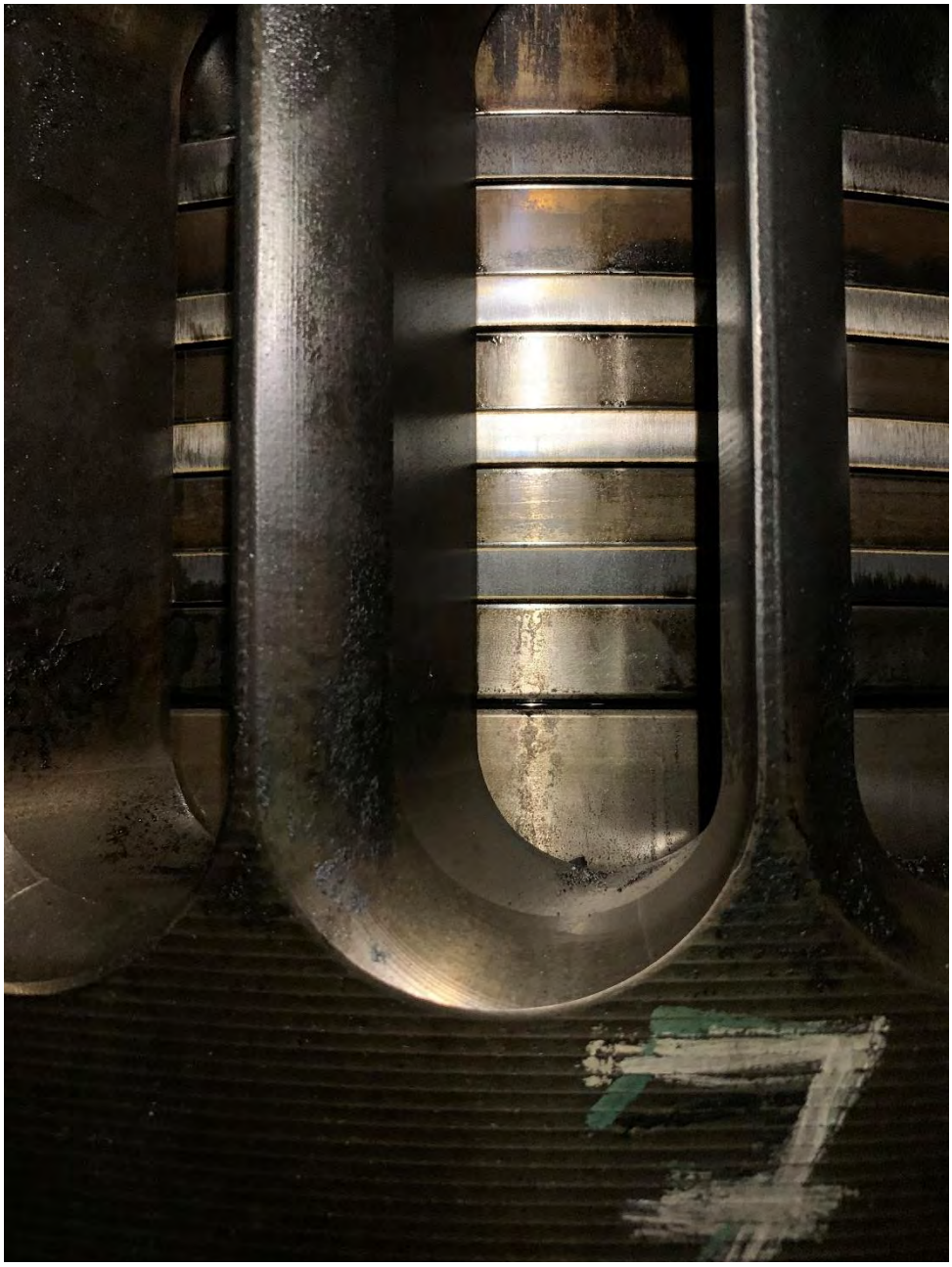
Unit #6 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits. 1st and 2nd rings appear to have been over-heated.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

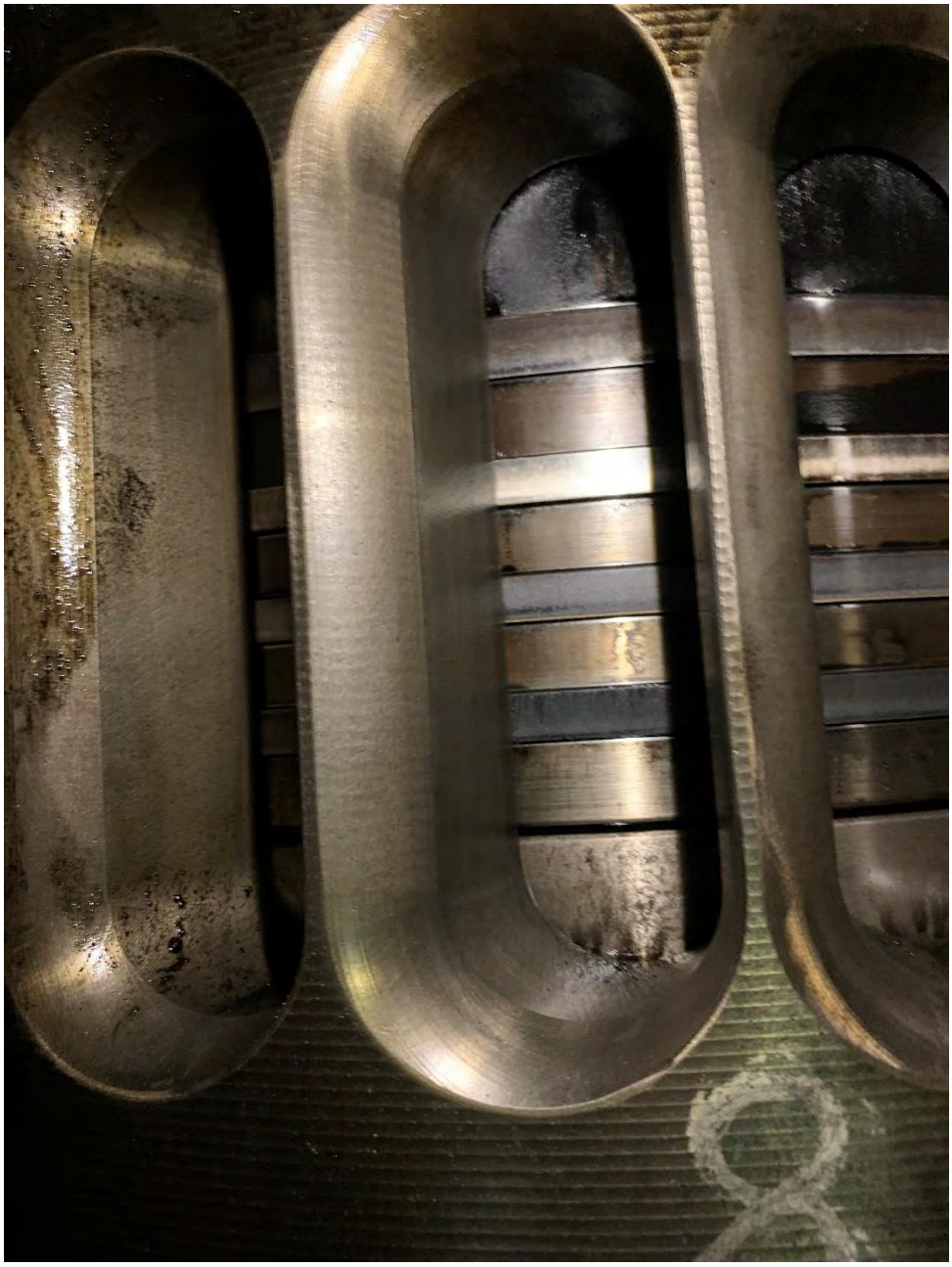
Unit #7 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits. Possible hard contact on 1st ring.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com

Unit #8 – Piston ring pack



Observations: Ring pack in good condition. No coke deposits.

Chris-Marine AB
Address: Stenyxegatan 3,
SE-213 76 Malmö, Sweden
Telephone: +46-40 671 2600. Fax: +46-40 671 2699
E-mail:info@chris-marine.com, www.chris-marine.com