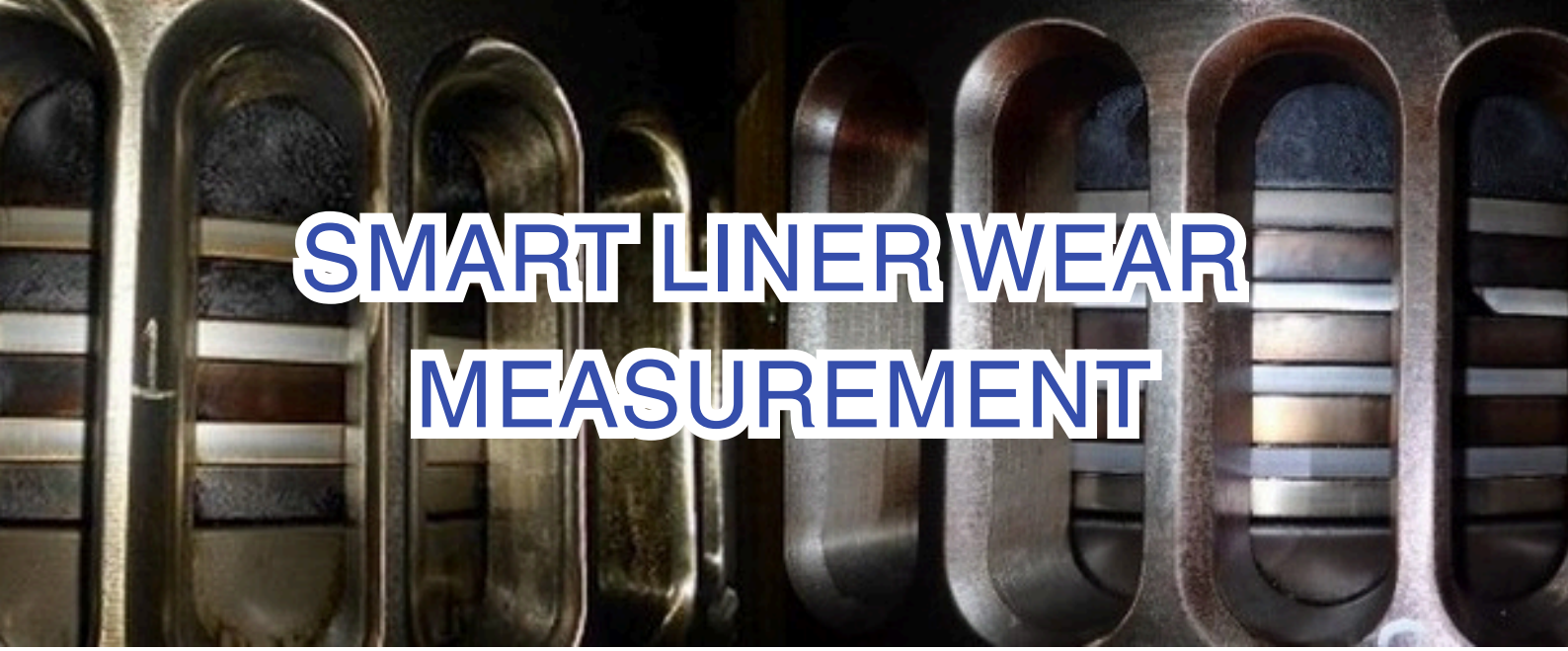


SMART LINER WEAR MEASUREMENT

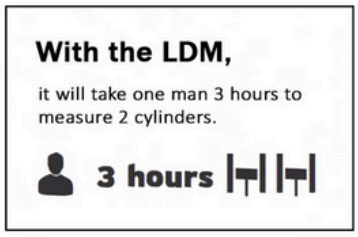
LDM is a SMART (Safe Measures, Accurate, Reliable & Time Saving) tool to analyse cylinder liner wear and clover-leafing.

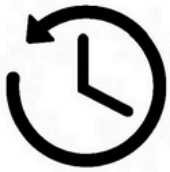
By using the LDM it is possible to avoid unplanned off-hire and reduce overhauling costs through continual monitoring of the cylinder condition before a piston overhaul will minimize downtime and cost.

Furthermore, pre-inspection of the cylinder condition before a piston overhaul will minimize downtime and cost.

Time Saving

Today's method of using a micrometer to determine liner wear will usually take a 3-man team and one long working day to measure 2 cylinders.





BENEFITS:

With the LDM it is possible to get an overview of several liners condition during even a short port stay, as no engine disassembly is necessary.

The measuring results are instantly available in Microsoft Excel format, where the results are clearly presented and 360° contour plots and trend plots can easily be prepared and shared. The results can be used as a stand-alone measurement in connection with troubleshooting, before dry-docking or as a measurement in a series to monitor the liner wear trend.

Further key features include:

- Approved as checked baggage according to IATA 2015 regulations
- Long-lasting battery user time: Approximately 13 hours of continuous usage without recharging

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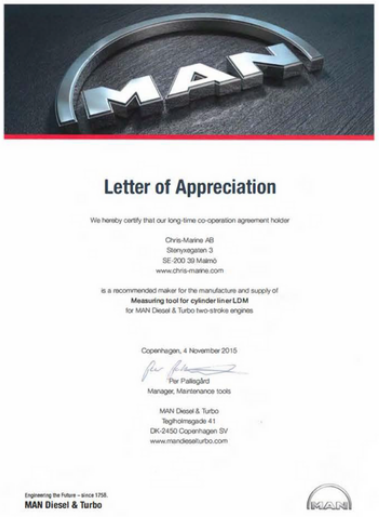
APPROVAL

The LDM was developed and tested in close cooperation with end users as well as marine workshops, engine builders and engine designers and significant importance was the cooperation with market leading low-speed engine designer MAN Diesel 8, Turbo.

As a result, MAN Diesel has issued a "No Objection Letter" as well as an approval certificate for the latest version of the measurement tool.

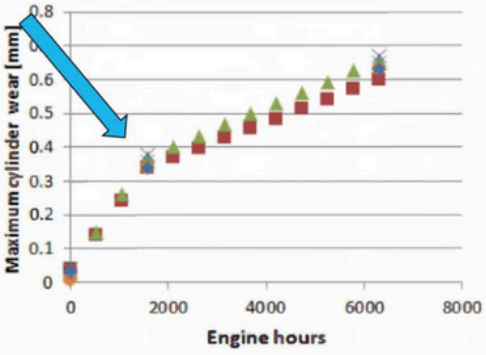


EXAMPLES FOR USE

1. EARLY DETECTION OF ABNORMAL CYLINDER WEAR AND VERIFICATION OF COUNTER-MEASURES

Abnormal cylinder wear can be caused by a variety of factors, such as:

- New engine type
- Slow-steaming
- New lube oil type or feed rate
- New bunker supplier (e.g. new route)
- New route (humidity, temperature and load change)
- Cat fines



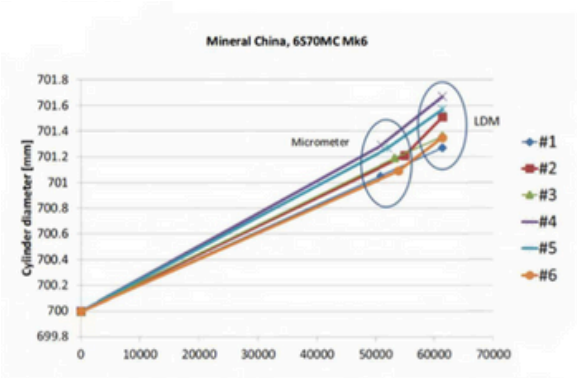
Date	2014-01-01	2014-02-01	2014-03-01	2014-04-01	2014-05-01	2014-06-01	2014-07-01	2014-08-01	2014-09-01	2014-10-01	2014-11-01	2014-12-01	2015-01-01
Engine hours	0	525	1050	1575	2100	2625	3150	3675	4200	4725	5250	5775	6300
Cylinder #1	0.04	0.14	0.24	0.34	0.37	0.40	0.43	0.46	0.49	0.51	0.54	0.57	0.60
Cylinder #2	0.03	0.15	0.26	0.37	0.40	0.43	0.47	0.50	0.53	0.56	0.59	0.63	0.66
Cylinder #3	0.02			0.38									0.67
Cylinder #4	0.04			0.36									0.65
Cylinder #5	0.01			0.34									0.63
Cylinder #6	0.03			0.34									0.63

In the above example, monthly LDM measurements were done for a new engine in units #1 and #2. The wear rate was found to be too high (0.2mm / 1 000h) and the root cause was traced as cold corrosion. The counter-measures included introduction of a new lubricant and to increase the cylinder wall temperature. The result could be clearly seen as reduced cylinder wear rate.

EXAMPLES FOR USE

2. VERIFY CYLINDER WEAR BEFORE DRY-DOCKING

It is normal practise to measure cylinder liners prior to dry-docking to find out if the cylinders need to be reconditioned (honed) or replaced during the docking.



The diagram on the right, indicates that all six cylinders were first measured manually with micrometer on six different occasions. During such measurements, the cylinder cover must be taken off and the procedure takes about one day per cylinder for a three-man team.

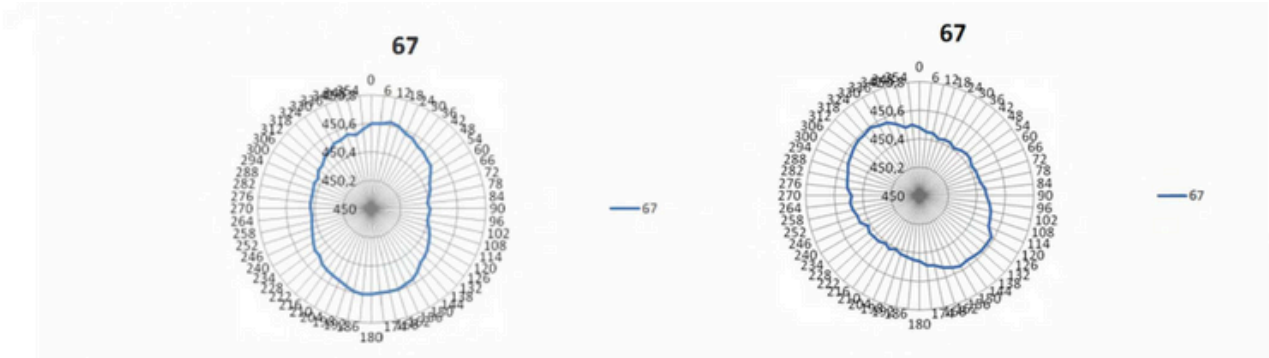
With the LDM, the same six cylinders could be measured on one working day and by one operator. The results were very similar.

3. DETECT ABNORMAL CYLINDER DEFORMATION AND WEAR BEFORE IT LEADS TO FAILURE

Clover shape and ovality can have different root causes, including cold corrosion and thermal deformation as a result from uneven cylinder temperatures.

The LDM allows you to take corrective action before the cylinder condition becomes critical, thereby saving costs and disturbance generated by emergency repair. Corrective actions often include adaptation of the cylinder cooling strategy or cylinder lubrication strategy.

EXAMPLE 1: 1 1 S90ME-C9

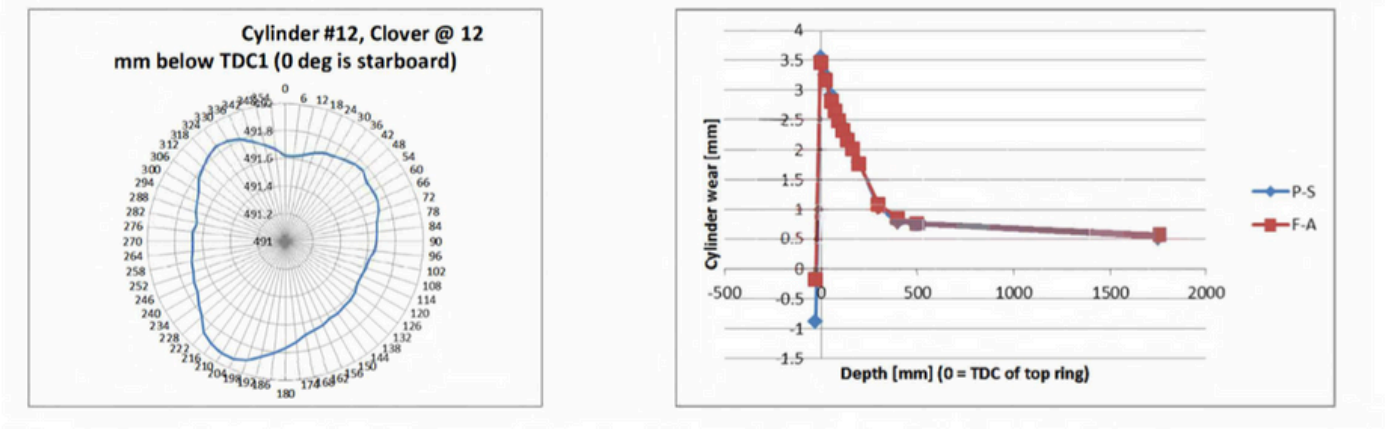


Cylinder 7, abnormal ovality. A broken stay bolt at 135 degrees has caused the ovality to rotate toward the broken bolt

Cylinder 3, normal ovality. The normal ovality shape for this engine is in the port-starboard direction (O degrees is port in the plot)

EXAMPLES FOR USE

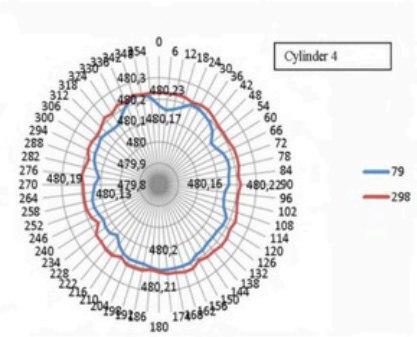
EXAMPLE 2: K98



Injection nozzle related wear. The three injectors have caused erosion in the cylinder liner, turning it into a three-clover. The diameter in the P-S and F-A directions are identical so no abnormality is picked up from a wear measurement. However, the clover measurement reveals that the cylinder is in poor condition and in need of honing or replacement.

EXAMPLE 3: RT FLEX 96

The image shows two clover-leafing measurements at 79mm and 298mm below top ring TDC.
Some clover shape can be seen at 79mm with peaks about 0.1 0mm higher than the valleys. Such a wear pattern will generate blow-by and eventually collapsed or broken piston rings when the piston ring pack cannot seal tightly against the cylinder liner.
Cylinder honing can restore the cylinder condition.



COMPATIBILITY

The LDM is suitable for all 2-stroke engines with 500 - 980mm bore, and offers fast and precise in-situ measurement of cylinder liner wear and shape with no need to remove cylinder cover or dismantle critical engine parts.

SUITABLE FOR ALL 2-STROKE ENGINES

MAN	SULZER	MITSUBISHI
MC/ME - C/G	RTA/RTFlex	UE/UEC
50	50	50
60	52	52
65	58	60
70	60	68
80	62	75
90	68	85
95	72	
98	76	
	82	
	84	
	96	

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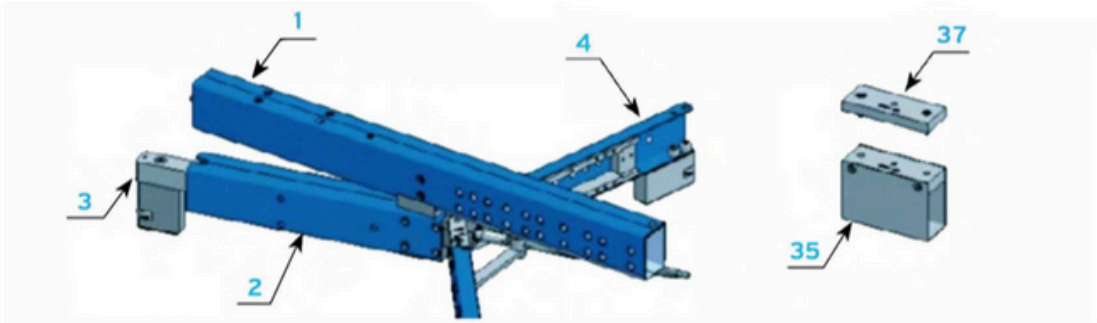
COMPATIBILITY

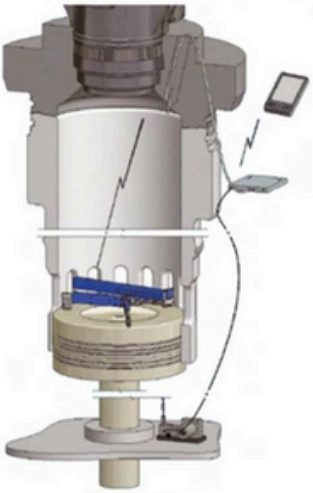
DIFFERENT ENGINE SIZES



The LDM can be adjusted to suit additional bore sizes by using extra parts:

- Support leg (3)
- Support beams (4)
- Counter-weight (35, 37)

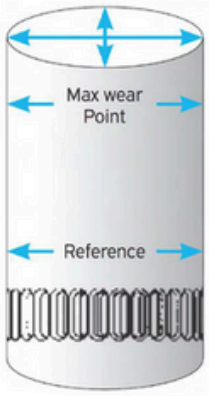
METHOD
HOW IT WORKS:



1. A height meter indicates the piston level
2. The height meter is wired to an interface box
3. The interface box has an antenna connected to it
4. The antenna is inserted into the combustion chamber through a hole in the cylinder cover
5. The interface box communicates wirelessly with the measurement arm and base and a hand-held computer (PDA)
6. The measurement base locks against the liner with a support leg at each measurement level
7. The rotating measurement arm can measure wear (4 radii, 1 minute) or clover (36 radii, 4 minutes) on each level
8. The liner wall temperature is measured with an IR sensor and compared with the internal device

WEAR MEASUREMENT DIRECTIONS

- One reference measurement is taken just above the scavenging ports
- Liner wear is then measured in depth positions of interest
- Several measurements are taken around the maximum wear position to ensure that the maximum wear is found
- Up to 60 radii clover leafing possible anywhere



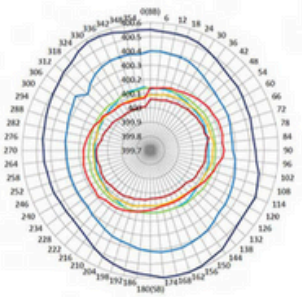
WEAR MEASUREMENT RESULTS

Id	Depth	P-S	F-A	P-S Dcyl	F-A Dcyl	Ovality	Tarm	Tcyl
12 (TDC1)	1	0.62	0.67	900.71	900.76	0.05	65	79
11	22	0.78	0.78	900.88	900.88	0.00	64	79
10 (TDC2)	44	0.86	0.92	900.96	901.02	0.06	63	77
9	65	0.87	0.89	900.97	900.99	0.02	61	75
8 (TDC3)	84	0.78	0.80	900.87	900.89	0.02	60	75
7	105	0.71	0.72	900.81	900.82	0.01	59	74
6 (TDC4)	123	0.67	0.69	900.77	900.79	0.01	57	73
5	146	0.61	0.65	900.70	900.75	0.04	55	72
4	201	0.54	0.52	900.64	900.62	0.02	53	72
3	300	0.27	0.31	900.37	900.41	0.04	50	70
2	402	0.20	0.29	900.29	900.38	0.09	47	70
0 (Ref)	2618	-0.03	0.04	900.06	900.13	0.07	43	46
1 (Ref)	2618	-0.02	0.02	900.07	900.12	0.04	43	47

MEASUREMENT RECIPE

General Information	
Vessel Name	Ship 1
Engine Type	S90ME
Engine builder	
Engine No	
Engine running hours	
Cylinder No	7
Liner drawing No	
PC-ring	
Cylinder running hours	6515
Cylinder running hours since last overhaul	
Cylinder cover tightened	True
Date	14-06-16 04:46:23
Remarks	
Operator	
Bore	900
Stroke	3260
Top land height	305
Ring center distance, 1-2	45
Ring center distance, 1-3	85
Ring center distance, 1-4	125
Ring center distance, 1-5	0
Reference depth	2618
Depths, ring center related	-22, 0, 22, 45, 65, 85, 105, 125, 145
Depths, additional	200, 300, 400
Wear ridge tracing	True

CLOVER-LEAFING MEASUREMENT: 2500, 2004, 1499, 1001, 501, 100, 24



- Measurement at a number of heights showing the profile change at different heights. S80-C9 engine.

LDM LINER DATA

Id	Depth corr	P-S corr	F-A corr	P-S Dcyl corr	F-A Dcyl corr	Ovality corr
17						
16 (TDC1)	1	1.76	1.55	501.76	501.55	0.21
15	16	1.77	1.62	501.77	501.62	0.15
14 (TDC2)	30	1.81	1.70	501.81	501.70	0.11
13	42	1.81	1.71	501.81	501.71	0.10
12 (TDC3)	55	1.83	1.72	501.83	501.72	0.11
11	67	1.82	1.73	501.82	501.73	0.09
10 (TDC4)	77	1.85	1.70	501.85	501.70	0.15
9	90	1.67	1.50	501.67	501.50	0.17
8	202	0.57	0.50	500.57	500.50	0.07
7	299	0.33	0.42	500.33	500.42	0.09
6	401	0.35	0.44	500.35	500.44	0.09
5	502	0.30	0.40	500.30	500.40	0.10
4	800	0.17	0.23	500.17	500.23	0.06
3	1100	0.14	0.25	500.14	500.25	0.11
2	1400	0.10	0.16	500.10	500.16	0.06
1 (Ref)	1551	0.11	0.16	500.11	500.16	0.05
1 (Ref)	1551	0.08	0.19	500.08	500.19	0.11
Correction	*0*			*0.00*	*0.00*	
Max		1.85	1.73	501.85	501.73	0.21

- Main Engine S50ME
- 20,217 hours
- Cylinder cover on
- 70 degC

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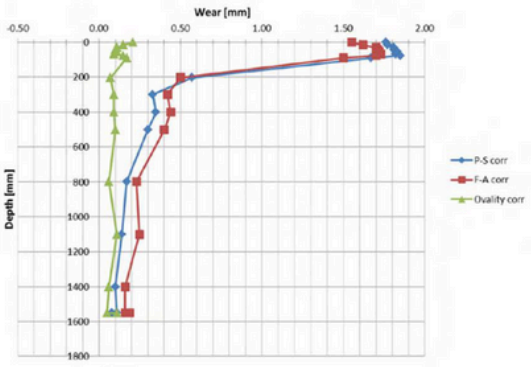
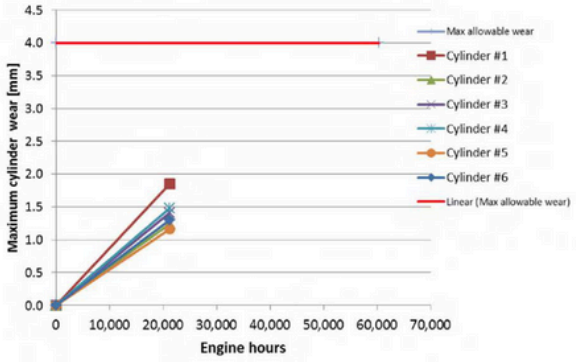
LDM LINER DEPTH VS WEAR GRAPH

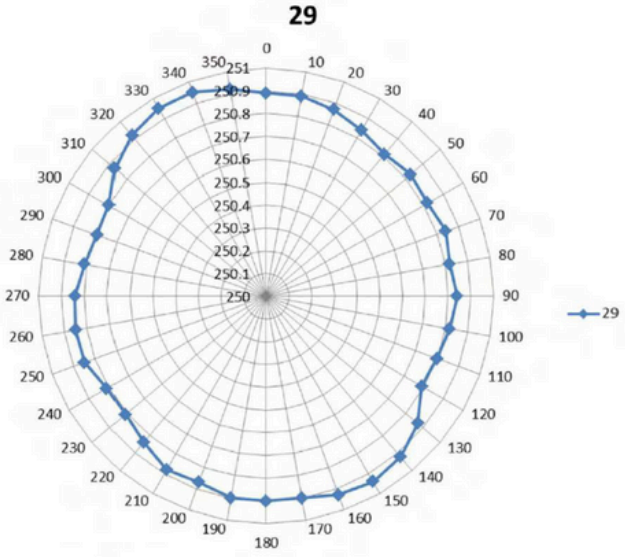


LINER HISTORY PLOT



CLOVER GRAPH ON TDC2

- The clover graph shows the liner wear and ovality pattern.
- Points 330°- 150° show ovality due to thrust forces acting on piston in the P-S.
- Points 260°- 80° show the Fuel Injectors wear effect.



WHAT WE OFFER

- On the spot measurement.
- Wear liner results.
- Professional report and analysis.
- Recommendations on repairs and counter-measures.
- Repair products and services when needed, such as:
- Liner shape restoration.
- Honing.
- Grinding.
- Wear edge removal.

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