CASE STUDY: Nuclear Emergency Diesel Generator - Poor Component Assembly

Summary

Following a periodic engine analysis activity, it was immediately noted by the analyst that Cylinder #2 had a peak firing pressure approximately 134 PSI lower than the engine average, the peak firing pressure was early ~3 degrees and exhaust temperatures were approximately 180 degrees F lower then engine average. The fuel pump and injector were replaced, the subsequent engine analysis data confirmed the problem had been corrected. After a root cause analysis and complete disassembly and inspection of the fuel pump revealed that two internal components were not installed during the last pump rebuild.

Background

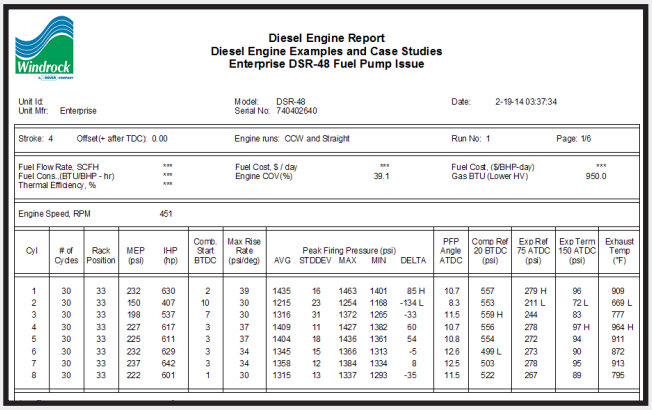
Emergency Diesel Generators at nuclear power plants worldwide provide a critical safety function to provide emergency power to critical equipment and systems in the event of a loss of site power. As such these engines are operated in test conditions periodically to ensure operation as well as tested after any maintenance activity is performed. In this instance the #2 EDG which is an 8 Cylinder Enterprise DSR-48 diesel engine rated at approximately 4890 Brake Horsepower was being operated as part of a periodic engine surveillance test and in which engine analysis was performed. The Windrock analyst noted the decreased firing pressure, early peak pressure and on a more detailed review noted that the fuel pump ultrasonic data had a double mechanical after the injector "popped". Less then 24 hours later the pump had been replaced, the engine returned to operational status.

Technology

The client contacted Windrock who used a 6320/DA portable analyzer to assess the condition and performance of the diesel engine. The 6320/DA analyzer measures dynamic data relative to crank position and then applies the principles of thermodynamics and science to precisely assess machinery condition and performance. The portable analyzer utilizes multiple sensor technologies to collect data degree-by-degree with respect to crank-angle. Measurement points include in-cylinder pressure, vibration and ultrasonic data on the cylinders. The system also measures vibration in the spectrum realm on the turbocharges and frame as well as angular velocity of the crankshaft. Using this information and built-in diagnostics, Windrock analyzers and software are able to assess the mechanical condition, performance and economic return of diesel engines.

Findings

A third-party company was tasked with a detailed inspection and disassembly of the pump to identify the root cause of the failure. This detailed inspection revealed that the Fuel Delivery Valve Stop and Fuel Delivery Fuel Valve Spring were not installed. Due to the design of this Fuel Delivery Valve, there was enough fuel being delivered for the cylinder to fire but at a reduced pressure. It was also noted that there was a through wall crack in the Delivery Valve Assembly. It is believed that this crack was caused by high pressure being built up in the pump due to the restricted flow area to the fuel injector.



Diesel Engine Report
Diesel Engine Examples and Case Studies
Enterprise DSR-48 Fuel Pump Issue

Unit Id:
Unit Mfr: Enterprise

Model: DSR-48
Serial No: 740402640

Date: 2-19-14 03:37:34

Stroke: 4 Offset(+ after TDC): 0.00

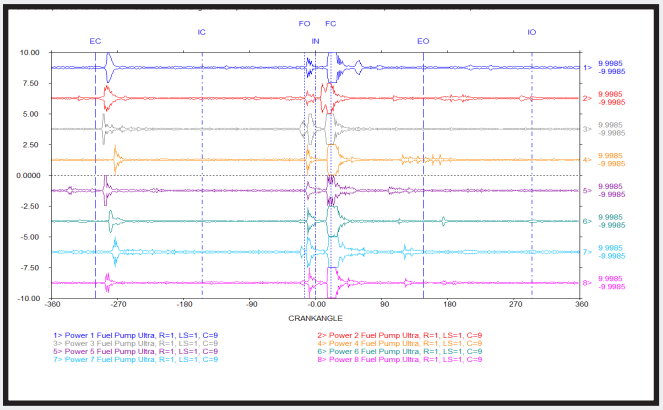
Engine runs: CCW and Straight

Run No: 1 Page: 1/6

Fuel Flow Rate, SCFH	***	Fuel Cost, $ / day	***	Fuel Cost, ($/BHP-day)	***
Fuel Cons.,(BTU/BHP - hr)	***	Engine COV(%)	39.1	Gas BTU (Lower HV)	950.0
Thermal Efficiency, %	***				

Engine Speed, RPM 451

Cyl	# of Cycles	Rack Position	MEP (psi)	IHP (hp)	Comb. Start BTDC	Max Rise Rate (psi/deg)	Peak Firing Pressure (psi) AVG	STDDEV	MAX	MIN	DELTA	PFP Angle ATDC	Comp Ref 20 BTDC (psi)	Exp Ref 75 ATDC (psi)	Exp Term 150 ATDC (psi)	Exhaust Temp (°F)
1	30	33	232	630	2	39	1435	16	1463	1401	85 H	10.7	557	279 H	96	909
2	30	33	150	407	10	30	1215	23	1254	1168	-134 L	8.3	553	211 L	72 L	669 L
3	30	33	198	537	7	30	1316	31	1372	1265	-33	11.5	559 H	244	83	777
4	30	33	227	617	3	37	1409	11	1427	1382	60	10.7	556	278	97 H	964 H
5	30	33	225	611	3	37	1404	18	1436	1361	54	10.8	554	272	94	911
6	30	33	232	629	3	34	1345	15	1366	1313	-5	12.6	499 L	273	90	872
7	30	33	237	642	3	34	1358	12	1384	1334	8	12.5	503	278	95	913
8	30	33	222	601	1	30	1315	13	1337	1293	-35	11.5	522	267	89	795



(Figure 1) Initial dataset showing low pressure on cylinder 2. (Figure 2) ultrasonic signature on fuel pump indicating the double hit on closure.

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Machine Protection

Condition Monitoring

Performance Analysis

Economic Evaluation

Analysis Details

This nuclear power station had just begun conducting engine analysis on their 3 EDG's and with this finding, which allowed for the immediate knowledge to identify the cause of the low pressure and temperature on this cylinder, is now performing engine analysis on their EDG' s regularly. This plant today is utilizing the latest technology in the form of multi-channel phased data collection of cylinder pressures, vibration and ultrasonic data.

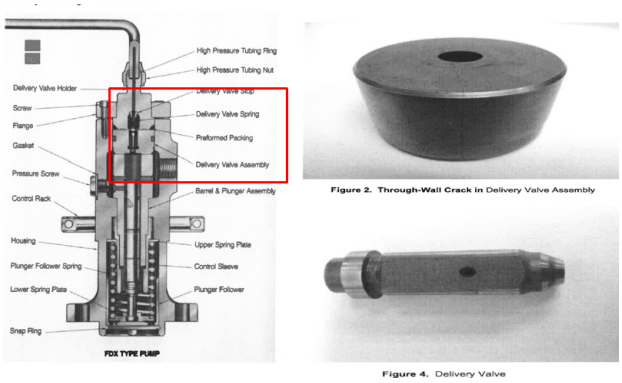
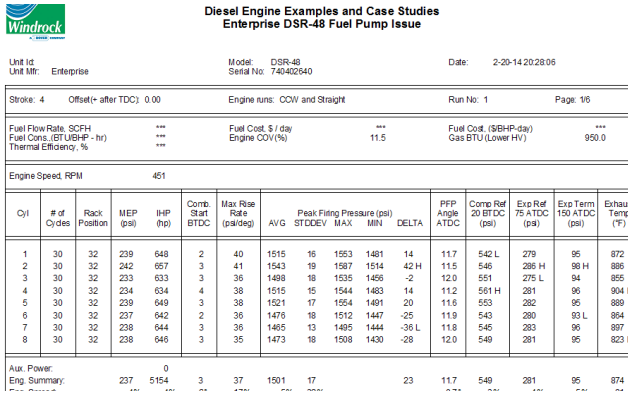


Figure 2. Through-Wall Crack in Delivery Valve Assembly

Figure 4. Delivery Valve

(Figure 4) Fuel Pump Assembly.



Diesel Engine Examples and Case Studies
Enterprise DSR-48 Fuel Pump Issue

Unit Id:
Unit Mfr: Enterprise

Model: DSR-48
Serial No: 740402640

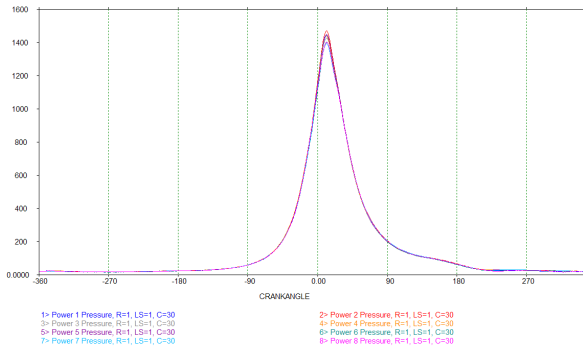
Date: 2-20-14 20:28:06

Stroke: 4 Offset(+ after TDC): 0.00 Engine runs: CCW and Straight Run No: 1 Page: 1/6

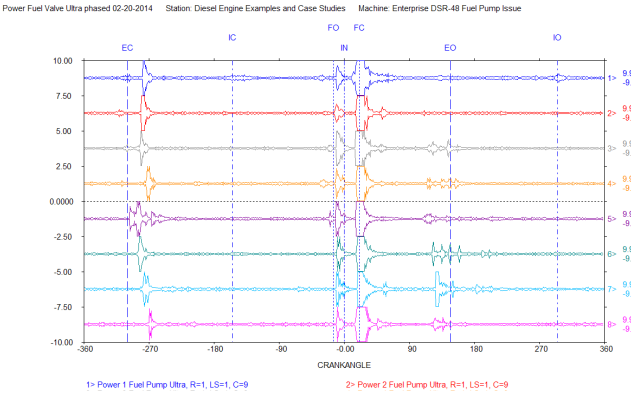
Fuel Flow Rate, SCFH	***					Fuel Cost, $ / day	***					Fuel Cost, ($/BHP-day)	***							
Fuel Cons. (BTU/BHP - hr)	***					Engine COV (%)	11.5					Gas BTU (Lower HV)	950.0							
Thermal Efficiency, %	***																			
Engine Speed, RPM	451																			

Cyl	# of Cycles	Rack Position	MEP (psi)	IHP (hp)	Comb. Start BTDC	Max Rise Rate (psi/deg)	Peak Firing Pressure (psi) AVG	STDDEV	MAX	MIN	DELTA	PFP Angle ATDC	Comp Ref 20 BTDC (psi)	Exp Ref 75 ATDC (psi)	Exp Term 150 ATDC (psi)	Exhau Temp (°F)
1	30	32	239	648	2	40	1515	16	1553	1481	14	11.7	542 L	279	95	872
2	30	32	242	657	3	41	1543	19	1587	1514	42 H	11.5	546	286 H	98 H	886
3	30	32	233	633	3	36	1498	18	1535	1456	-2	12.0	551	275 L	94	855
4	30	32	234	634	4	38	1515	15	1544	1483	14	11.2	561 H	281	96	904
5	30	32	239	649	3	38	1521	17	1554	1491	20	11.6	553	282	95	889
6	30	32	237	642	2	36	1476	18	1512	1447	-25	11.9	543	280	93 L	864
7	30	32	238	644	3	36	1465	13	1495	1444	-36 L	11.8	545	283	96	897
8	30	32	238	646	3	35	1473	18	1508	1430	-28	12.0	549	281	95	823
Aux. Power:				0												
Eng. Summary:			237	5154	3	37	1501	17			23	11.7	549	281	95	874

(Figure 5) Post repair combustion data.



(Figure 6) Normal Trace data.



(Figure 7) Normal Ultrasonic data.

About Windrock

Windrock offers industry-leading expertise in condition-based and performance-based monitoring solutions for compressors and engines across multiple applications. We design and manufacture portable analyzers and online systems at our headquarters in Knoxville, TN. In addition to our products, Windrock Technical Services analysts travel the world to help companies with their reliability and maintenance programs. We are proud to be a part of Dover Energy Automation (a Dover Corporation company).

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