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Machines only Stop Working after their Parts Fail

Abstract:

Machines only Stop Working after their Parts Fail. The level of care given to an equipment item depends directly on the size of business risk if it fails. Reduce the chance of its failure and you increase its reliability. It becomes vital to know the full range of risks each part within an equipment item will suffer. The right asset management strategy starts by knowing which parts are at risk and it is completed when the necessary actions to prevent all failures are in use. Asset Management that does not identify all the risks to equipment parts when selecting equipment maintenance and operating strategies will get you doing the wrong work.

Keywords: maintenance strategy selection, failure prevention, asset management strategy

How do you get high equipment reliability, low maintenance costs and world class production uptime? We know those outcomes are the result of applying the right practices across the asset life cycle and that you need to design your business systems to intentionally deliver them. If you want world class operational performance you cannot have it by accident or luck. To have highly reliable production plant, machines and equipment it is necessary to ensure that they do not fail, and are not failed, from their operating circumstances.

Figure 1 shows a typical electric motor drive end bearing and housing assembly. From the drawing we can construct the flow chart of how it works. The diagram for the drive end bearing and housing is shown in Figure 1. The flow chart makes it clear that the motor is made of a chain of parts strung together. All machines are designed and built in the same way—parts put together in long series. This is an arrangement at high risk of ruin and it explains why high reliability is so difficult to get—break a part, any part along the chain, and the whole machine fails.

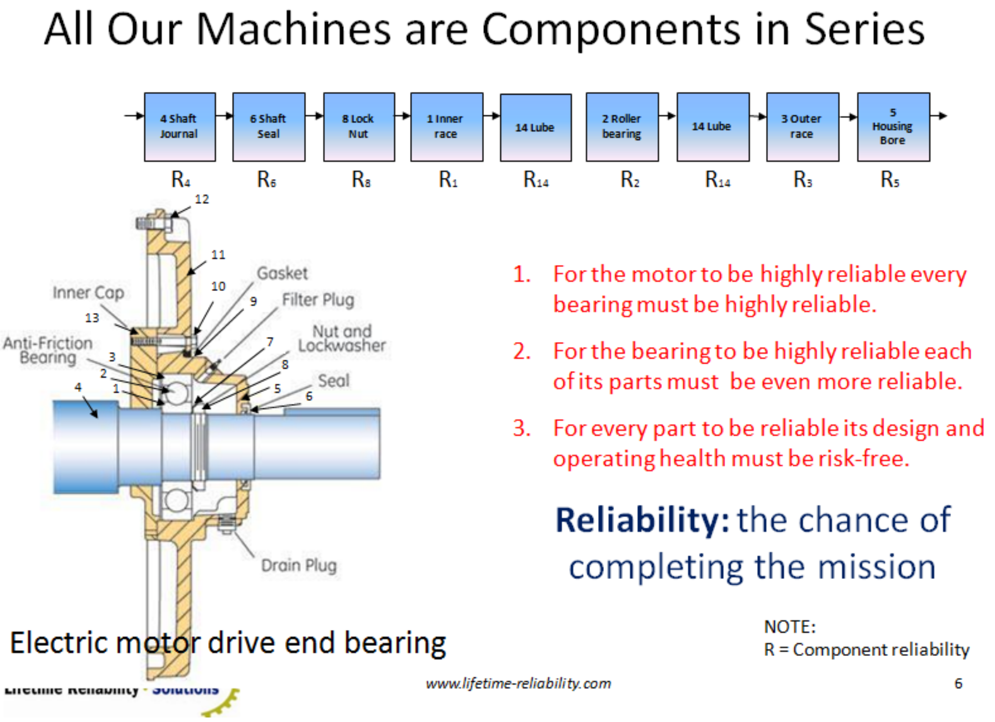

Figure 1 – Every Machine is a Long Chain of Parts

Reliability engineering analysis tells us that the failure rate of machines is the sum of the failure rate of the parts. Figure 2 represents a 3-part machine and shows how the machine failure rate is the addition of its individual parts' failure rate.

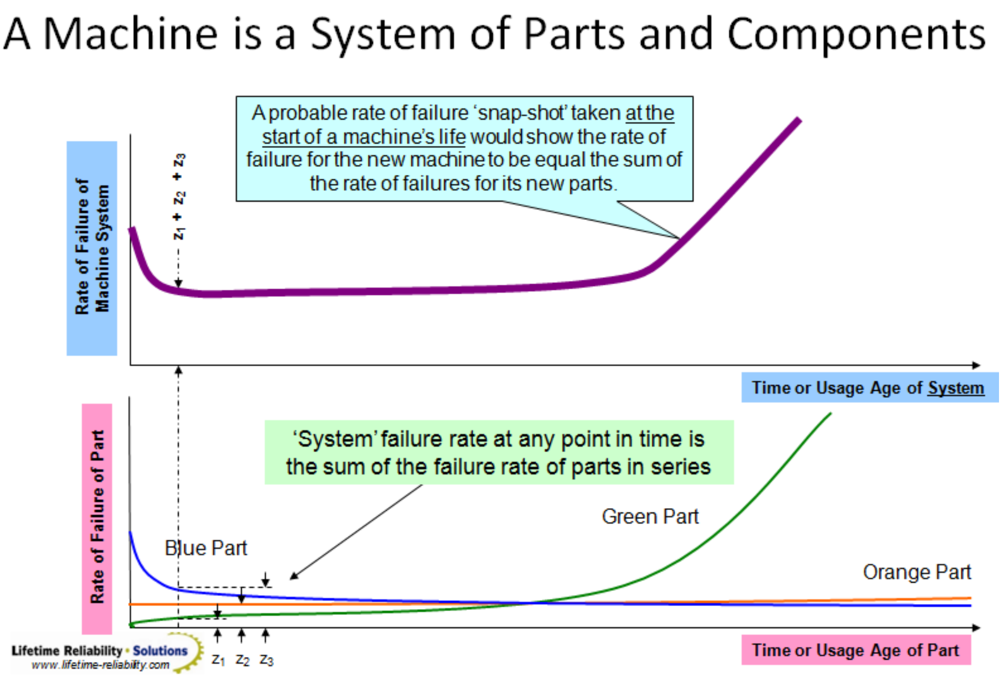

Figure 2 – A Machine's Failure Fate is the Sum of Its Parts Failure Rates

Figure 3 shows the three parts failure history and the effect it has on the machine downtime. First a part fails and then the machine stops. The secret to world class reliability success is in the last sentence—prevent a machine's parts from failing and you will create a highly reliable machine. The machine failure rate has the naming convention ROCOF—Rate of Occurrence of Failure.

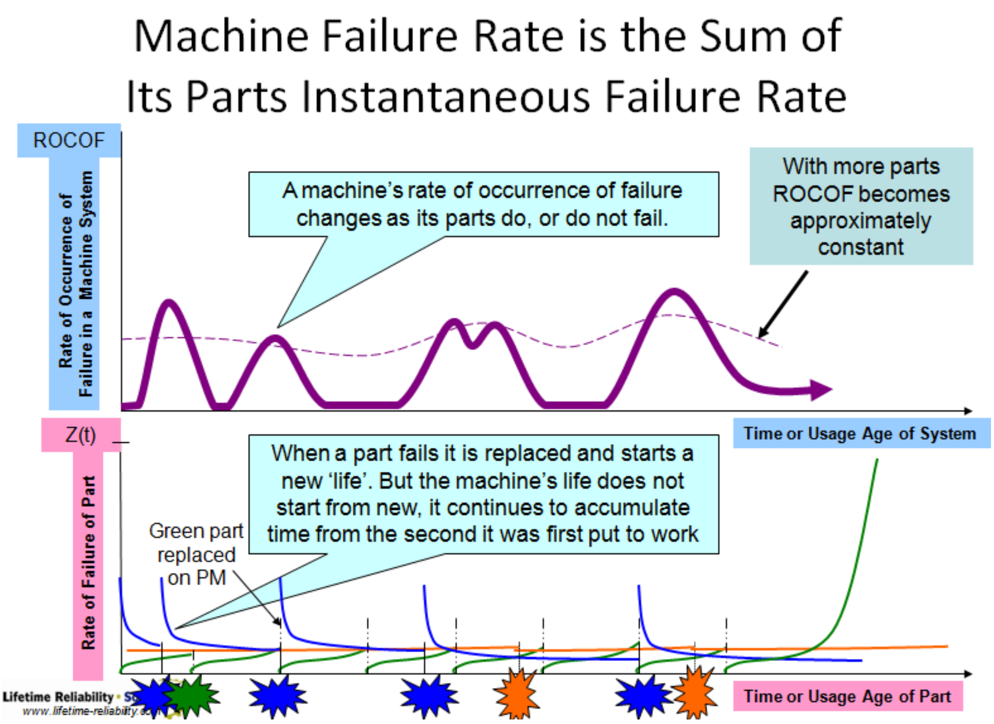

Figure 3 – A Machine Fails because its Parts First Fail

When the working parts are not failed the machine continues to operate. When the working parts fail the machine is stopped. The message to take-away is simple and clear—if you want to create a reliable machine then stop its working parts from failing. A working part is a component, including lubricant, which must be present for the equipment to function properly and faithfully meet its duty. Most reasons machine parts fail are indicated for the 'bathtub' curve of Figure 4. Every time the 'chain' of parts is broken (any part, anyhow, anytime) a machine dies. Mostly parts fail because poor business processes do not prevent materials-of-construction over-stress and/or stop human error. Plant and equipment failures are no accident; your machines are sent to their deaths[1].

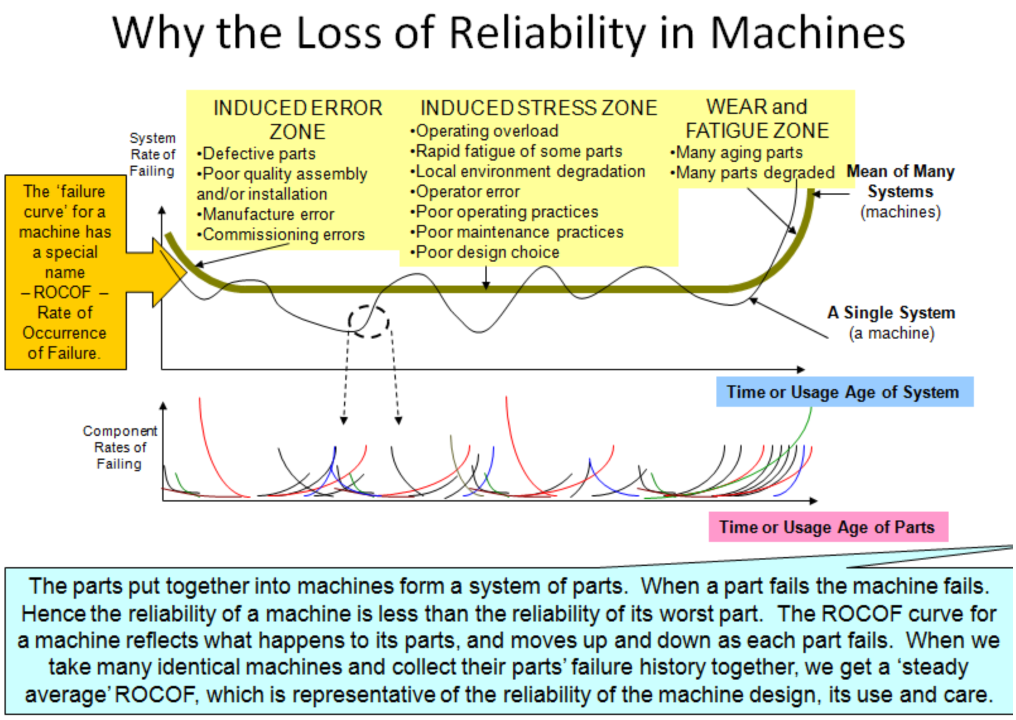

Figure 4 – Parts are failed for only a Few Reasons, though each has Many Causes

Select Operating and Maintenance Strategy that Prevent the Risk of Parts Failure

A highly reliable machine needs strategies and practices across its life-cycle that reduces the chance of its parts failing in operation. When you keep working parts in top condition you make machines reliable. This makes the aim of your operating and maintenance strategy twofold:

1. First create the right conditions inside your machinery and equipment for their working parts to naturally have long, reliable and productive lives by removing all risks of over-stress.
2. Secondly, proactively keep the conditions of working parts to within their ideal operating envelope by putting in-place the right reliability practices and preventing human error.

Where these two requirements cannot be achieved failure and maintenance result.

Intentionally create the exact situations that make the working parts in your machines live for a very long time. You will see a huge growth in production plant availability when you introduce the causes of reliability. Figure 5 shows the very few activities to focus on to stop equipment failures. You make machines highly reliable by using your business management systems, maintenance strategies and operating practices to deliver sure, failure-free operation. Teach your people exactly how to cause reliability, document it precisely and refresh that education regularly.

[1] Bennett, Rod, *'Machines don't die;… they're murdered!'*, SIRFRt Condition Monitoring National Forum, 8th – 11th August 2006, Practices Leader Condition Monitoring, Silcar, Australia

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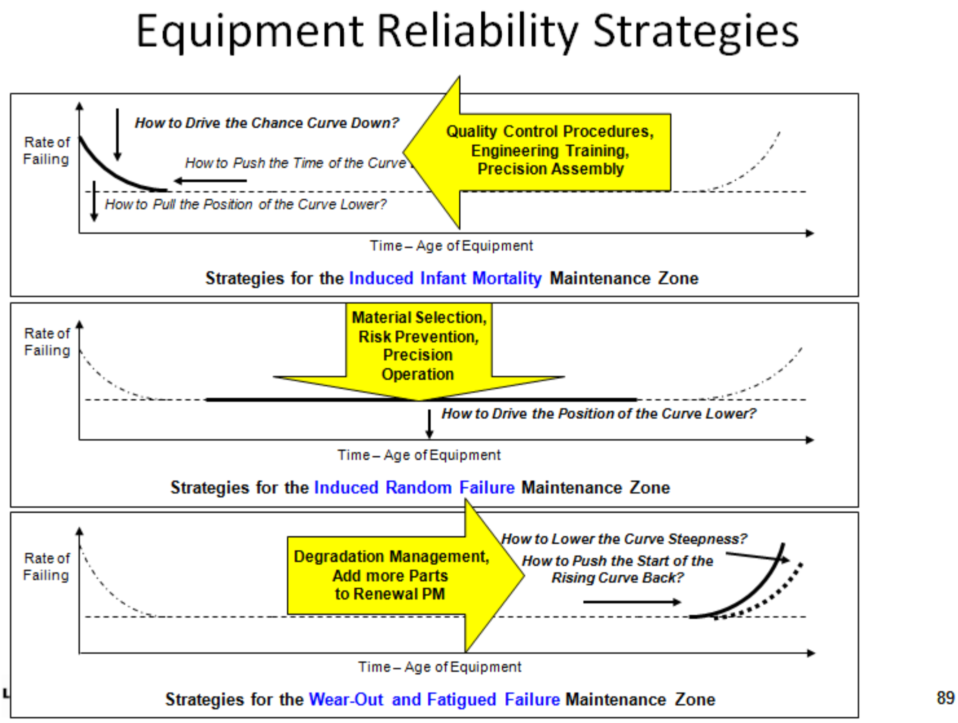

Figure 5 – We Know Exactly How to Control and Prevent Equipment Failure

The effect will be like that shown in Figure 6 where machine failure rates fall as fewer and fewer parts are put at risk of failure.

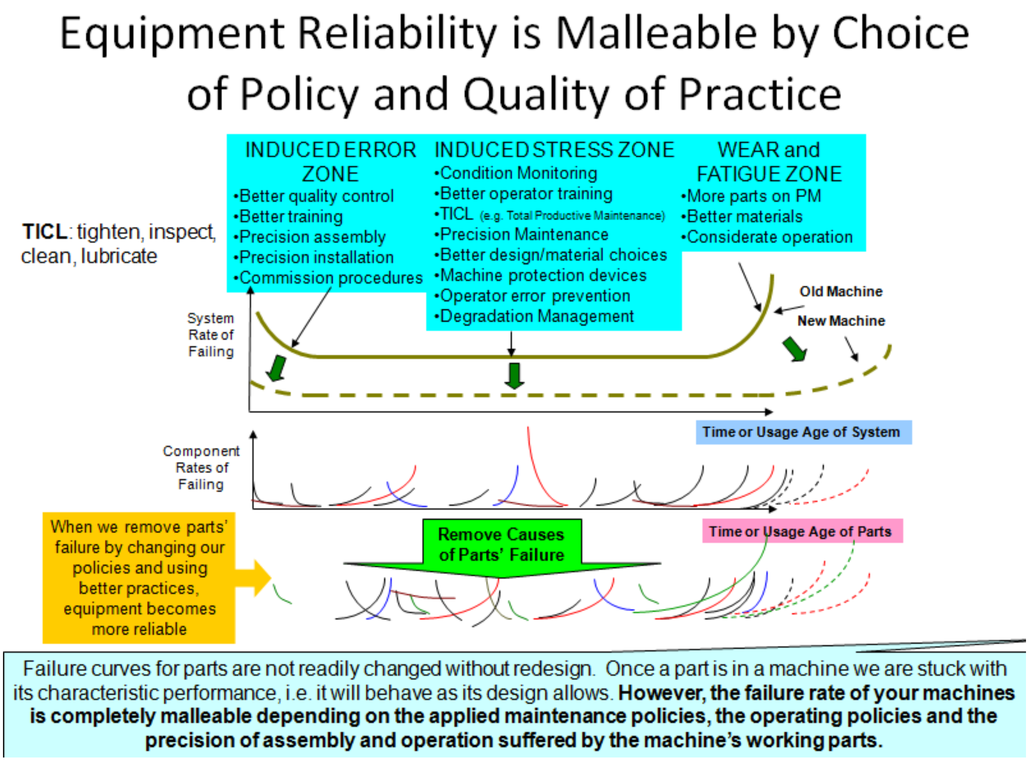

Figure 6 – Prevent Parts from Failing and You Create Equipment Reliability

Identifying Parts at Risk

To identify the parts at risk of failure in your equipment you only need the parts drawings and Bill

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of Materials (BOM) like those shown in Figures 7 and 8.

Parts at Risk of 'Induced' Age and Stress

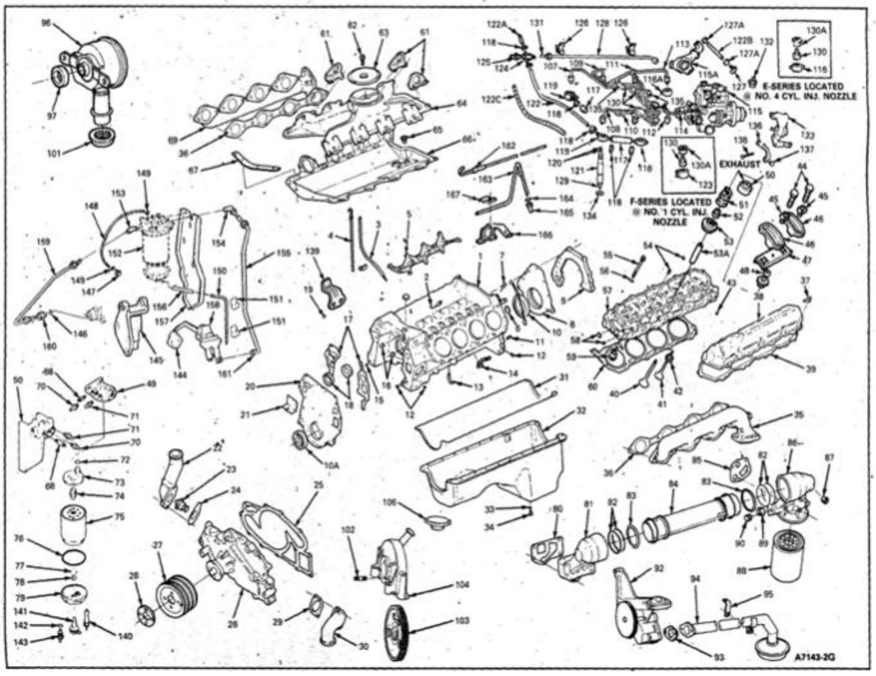

Figure 7 – Exploded Parts Drawing

On the BOM parts list you identify the working parts that can fail and the types of failure causes that they can suffer—error, induced stress, and wear-and-tear. Once you know the risks and where they will come from you use your business management systems to prevent them from happening.

Using Bills of Materials for Operating Risk Reduction and Maintenance Selection

REF. NO.	BASIC PART NO.	DESCRIPTION	Type
1	6009H	Cylinder Block Assy.	*
2	6C329A	Guide, Tappet	^
3	6754	Tube Assembly, Oil Level Gauge (F-Series)	^
4	6750	Oil Level Gauge (F-Series)	^
5	6C330A	Retainer, Tappet Guide	^
6	6026A	Plug, Engine (1-1/2" O.D.)	^
7	6D083A	Gasket, Rear Cover	^
8	6L080A	Cover Assembly, Engine, Rear	^
9	6A369A	Adapter, Flywheel to Transmission	^
10	6701A	Rear Oil Seal, Crankshaft	^*
10A	—	Front Oil Seal	^*
11	6B041B	Dowel Pin, Fly Wheel Adapter	^
12	87614S	Pipe Plug, 1/8 NPTF	^
13	6C327A	Piston Cooling Jet	
14	6A051A	Heater Assembly, Block	
15	6B041A	Dowel Pin, Front Cover Plate	
16	6026E	Cup Plug	
17	6020A	Gasket, Front Cover Plate	
18	6A251A	Bearing Kit, Camshaft	
19	6A528A	Ball, Oil Indicator Hole 11/32"	
20	6B070A	Plate, Front Cover	
21	-	Indicator, Timing (Part of Front Cover)	
22	8592G	Connection, Water Outlet	
23	8575	Thermostat	
24	8255A	Gasket, Water Outlet	
25	8507A	Gasket, Water Pump	
26	8501D	Water Pump	^*•
27	8509D	Pulley, Water Pump	^*
28	8546A	Spacer, Fan	^
29	8255A	Gasket, Water Inlet	
30	8592D	Connection, Water Inlet	
31	D6AZ-19562-A	RTV Sealant	
32	6675C	Oil Pan	
33	6734A	Gasket, Oil Pan Drain	
34	6730A	Plug, Oil Pan Drain	
35	9431B	Manifold, Exhaust, Left	
36	9448A	Gasket Exhaust Manifold	
37	6A532A	Washer, Valve Cover	
38	6582C	Valve Cover	
39	6584A	Gasket, Valve Cover	
40	6507D	Valve, Intake (8)	*•
41	6505	Valve, Exhaust	*•
42	6057B	Insert, Exhaust Valve Seat	*^
43	6026F	Plug, Ball Type 13/32" (8)	
44	—	Bolt, Valve Lever and Washer	

REF. NO.	BASIC PART NO.	DESCRIPTION	Type
45	—	Post, Valve Lever	
46	—	Lever, Valve	
47	—	Retainer, Valve Lever Post	
48	—	Lock, Valve Spring Retainer	
49	6514A	Retainer, Valve Spring (36)	
50	—	Shield, Oil (Exhaust)	
51	6513B	Spring, Valve, with Damper (16)	
52	6571A	Seal, Valve Stem-Intake (8)	
53	6K533A	Rotator, Assembly Valve (16)	
53A	—	Guide, Valve (Service)	
54		Plug, 1/2 inch NPTF (4)	
55	6065A	Bolt Cylinder Head (34)	
56	6L015A	Washer, Cylinder Head Bolt (34)	
57	6049A	Cylinder Head Assembly (2)	
58	6026B	Plug, 1/4 Inch	
59	6057A	Insert, Combustion Chamber (8)	
60	6051B	Gasket, Cylinder Head (2)	
61		Eye, Lifting (3)	
62	9C629A	Insert, Bolt Thread-Air Cleaner Stud	
63	9F460A	Screen, Intake Manifold	
64	9424B	Manifold, Intake	
65	9A450A	Drain Plug, Valley Pan	
66	9439B	Gasket and Valley Pan	
67	9B470A	Strap, Valley Pan	
68		Fuel Priming Valve and Cap	
69	9430A	Manifold, Exhaust, Right	
70		Continuous Vent with Check Valve	
71		Vacuum Switch (Fuel Filter Element Replacement Indicator)	
72		Fuel Heater O-Ring	
73		Fuel Heater	
74		Threaded Insert	
75		Fuel Filter Element	^+
76		Drain Bowl O-Ring	
77		Drain Valve Stem Cap	
78		Drain Valve Seal	
79		Water Separator Drain Bowl	
80	6A636A	Gasket, Oil Cooler, Front Header	
81		Header, Oil Cooler, Front	
82	6K649A	O-Ring, Oil Cooler (2)	
83	6C610A	O-Ring, Oil Cooler (2)	
84	6A642A	Cooler, Oil	
85	6A636B	Gasket, Oil Cooler, Rear Header	
86	6881B	Header, Oil Cooler, Rear	
87	6K862A	Plug, 1/4-Inch	
88	6731A	Oil Filter	^+

REF. NO.	BASIC PART NO.	DESCRIPTION
89		Plug, 1/2 Inch
90		Plug, 1/2 Inch
92	6600	Oil Pump Assy.
93	6626	Gasket, Oil Pick-Up
94	6622	Pick-Up Tube
95	6A661	Bracket, Oil Pick-Up
96	6A665	CDR Valve
97	6A892	Seal Ring, CDR Valve
100	6758	Crankcase Vent Tube
101	6769	Grommet, Valley Cover
102	9F733	Mounting Stud, Injection Pump
103	9A546	Drive Gear, Injection Pump
104	9C516	Adapter Housing, Injection Pump
106	6766	Cap, Oil Filler
107	9A555H	Pipe w/Nuts Pump to Cyl. 8
108	9A555G	Pipe w/Nuts Pump to Cyl. 7
109	9A555F	Pipe w/Nuts Pump to Cyl. 6
110	9A555E	Pipe w/Nuts Pump to Cyl. 5
111	9A555D	Pipe w/Nuts Pump to Cyl. 4
112	9A555C	Pipe w/Nuts Pump to Cyl. 3
113	9A555B	Pipe w/Nuts Pump to Cyl. 2
114	9A555A	Pipe w/Nuts Pump to Cyl. 1
115	9A543	Injection Pump
115A	—	Valve, Vacuum Modulator (Auto. Trans.)
116	—	Fuel Return Tee
116A	—	Elbow, Fuel Return (F-Series)
117	—	Hose
118	9B255	Clip
119	9A564	Fuel Return Tee
120	87032-S92	O-Rings
121	9E527	Injection Nozzle Holder
122	—	Fuel Return Hose
122A	—	Hose
122B	—	Hose, Pump to Fuel Return Tube
122C	—	Guard, Rear Fuel Return Hose
123	—	Fuel Return Tee (E-Series)
124	9F734	Fuel Return Junction Fitting
125	—	Nipple, Fuel Return
126	9N659	Clamp
127	9F736	Elbow
127A	—	Clip
128	9D308	Tube
129	—	Nozzle Tip
130	—	Sensor, Fuel Line Pressure
130A	—	Cover
131	9C387	Sleeve Seal, Fuel Return (2)

REF. NO.	BASIC PART NO.	DESCRIPTION
132	9E939	Temperature Switc
133	12B526	Bracket and Solen
134	—	Gasket Nozzle (8)
135	9N653	Clamp
136	9F541	Kickdown Lever (
137	9D927	Screw, Kickdown
138	9F539	Adjusting Screw (
139	6786	Bracket, Oil Leve (F-Series)
140		Vent/Valve Assen
141		Manual Drain Va
142		Water Sensor O-
143		Water Sensor Pr
144		Fuel Pump Supp
145		Alternator Bracket
146		Sealing O-Ring
147		Fuel Return Tee (At Nozzle)
148		Hose, 3/16" ID x 10" Long
149		Hose Clip
150		Water Drain Tube
151		Drain Tube Clamp (2)
152		Fuel Filter/Water Separator Element
153		Elbow
154		Elbow, Fuel Supply Pump to Filter Header
155		Fuel Pump to Fuel Header Tube (With Two Nuts and Two Sleeves)
156		Hose, 3/16" x 2-5/16" Long
157		Fuel Filter Header Mounting Bracket
158		Fuel Supply Pump
159		Filter to Injection Pump Tube (With Two Nuts and Two Sleeves)
160		Connector Fitting
161		Inverted Flare Tube Nut
162		Oil Level Gauge — E-Series
163		Tube Assembly, Oil Level Gauge — E-Series
164		O-Ring, Oil Level Gauge — E-Series
165		Oil Level Gauge Tube, Lower — E-Series
166		Bracket, Oil Level Gauge Tube — E-Series
167		Retainer, Oil Level Gauge Tube — E-Series

* **Wear-out** (age related failure)
\+ **From Usage** (contaminates with use)
• **Induced Stress** (random failure)
^ **Induced Error** (early Life Failure)

Figure 8 – Bill of Materials Identifying Failure Types for Working Parts

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Focus on Prevention Instead of Cure

The end we want is to achieve a very particular outcome for our plant, machines and equipment—long, failure-free operating lives. Using predictive strategies like reliability modelling, condition monitoring and preventive maintenance are necessary but poor ways to care for machines and equipment because they permit their failure. They are not failure prevention strategies. They are maintenance and repair strategies that need failures to exist for them to be used and their use invites countless outages to replace failing parts and to fix frequent breakdowns. You will achieve far greater reliability more quickly by focusing your effort, time and money on preventing the risks that cause equipment failure than by looking for failures starting and then correcting the problems. Figure 9 shows the defect prevention strategy to adopt for long-lived, highly reliable equipment—remove the causes of failure by providing the ideal conditions for outstanding parts reliability.

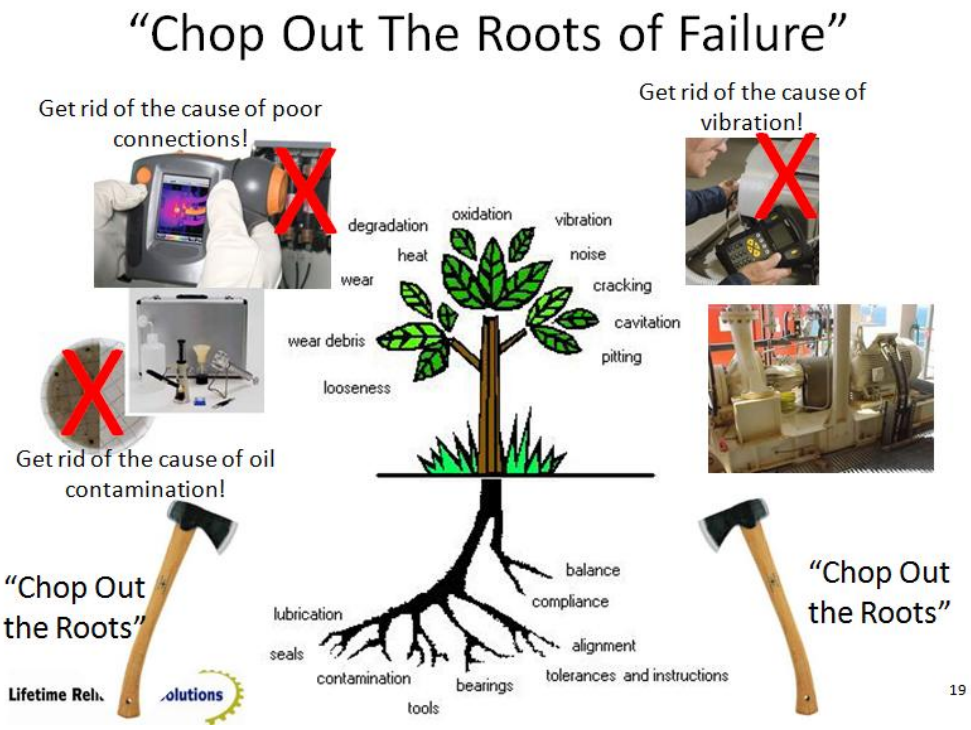

Figure 9 – Prevent Machine Failures by Preventing the Risk of Failures for Working Parts

Conclusion

Machines intentionally need be treated in the right ways that produce failure-free operation. It requires designing life-cycle business processes that remove the risks of failure to the 'chain-of-parts' in your machines by making sure every working components in your plant, machinery and equipment are actively given the necessary conditions for low-stress, error-free operation. Identify the design, operational and maintenance activities that produce high parts reliability and then build business process to deliver them successfully to your operating plant and equipment. Work on removing the risks to the 'chain-of-parts' in your machines so they cannot break.

My best regards to you,

Mike Sondalini
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