Tribological Reliability in Turbomachinery

Predictive and Proactive Maintenance

Javier Vázquez-Dodero

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Importance of Lubrication

The importance of lubrication

COLFAX® Fluid Handling | SICELUB® LUBRITECH®

The importance of lubrication

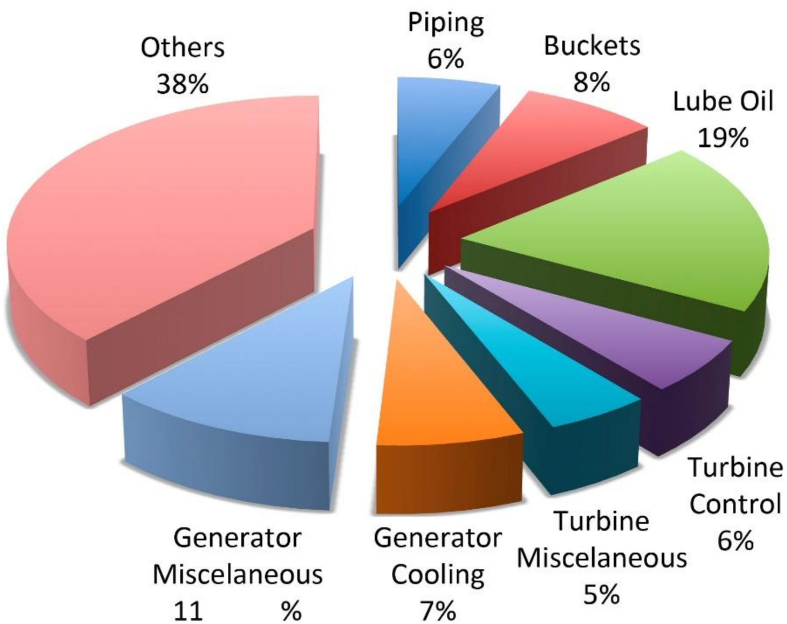
	20/17		19/16		18/15		17/14		16/13		15/12.		14/11.		13/10.		12/9.		11/8.		10/7.	
26/23	5	3	7	3.5	9	4	>10	5	>10	6	>10	7.5	>10	9	>10	>10	>10	>10	>10	>10	>10	>10
	4	2.5	4.5	3	6	3.5	6.5	4	7.5	5	8.5	6.5	10	7	>10	9	>10	10	>10	>10	>10	>10
25/22	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	7	>10	9	>10	>10	>10	>10	>10	>10
	3	2	3.5	2.5	4.5	3	5	3.5	6.5	4	8	5	9	6	10	7.5	>10	9	>10	>10	>10	>10
24/21	3	2	4	2.5	6	3	7	4	9	5	>10	6	>10	7	>10	8	>10	10	>10	>10	>10	>10
	2.5	1.5	3	2	4	2.5	5	3	6.5	4	7.5	5	8.5	6	9.5	7	>10	8	>10	10	>10	>10
23/20	2	1.5	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	8	>10	9	>10	>10
	1.7	1.3	2.3	1.5	3	2	3.7	2.5	5	3	6	3.5	7	4	8	5	10	6.5	>10	8.5	>10	10
22/19	1.6	1.3	2	1.6	3	2	4	2.5	5	3	7	3.5	8	4	>10	5	>10	6	>10	7	>10	>10
	1.4	1.1	1.8	1.3	2.3	1.7	3	2	3.5	2.5	4.5	3	5.5	3.5	7	4	8	5	10	5.5	>10	8.5
21/18	1.3	1.2	1.5	1.5	2	1.7	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	7	>10	10
	1.2	1.1	1.5	1.3	1.8	1.4	2.2	1.6	3	2	3.5	2.5	4.5	3	5	3.5	7	4	9	5.5	10	8
20/17			1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	5	>10	7	>10	9
			1.2	1.05	1.5	1.3	1.8	1.4	2.3	1.7	3	2	3.5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19/16					1.3	1.2	1.6	1.5	2	1.7	3	2	4	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
					1.2	1.1	1.5	1.3	1.8	1.5	2.2	1.7	3	2	3.5	2.5	5	3.5	7	4.5	9	6
18/15							1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4.5	>10	6
							1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	3.5	2.5	5.5	3.7	8	5
17/14									1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	6	3	8	5
									1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	4	2.5	6	3.5
16/13											1.3	1.2	1.6	1.5	2	1.7	3	2	4	3.5	6	4
											1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.8	3.7	3	4.5	3.5
15/12.													1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5
													1.2	1.1	1.5	1.4	1.8	1.5	2.3	1.8	3	2.2
14/11.															1.3	1.3	1.6	1.6	2	1.8	3	2
															1.3	1.2	1.6	1.4	1.9	1.5	2.3	1.8
13/10.																	1.4	1.2	1.8	1.5	2.5	1.8
																	1.2	1.1	1.6	1.8	2	1.6

Máquinas Hidráulicas y Motores	Rodamientos
Chumaceras y Turbomaquinaría	Cajas de Engranes y otros

3x Bearing Life Extension

Reliability and Lubrication

Reliability and Lubrication. Turbines



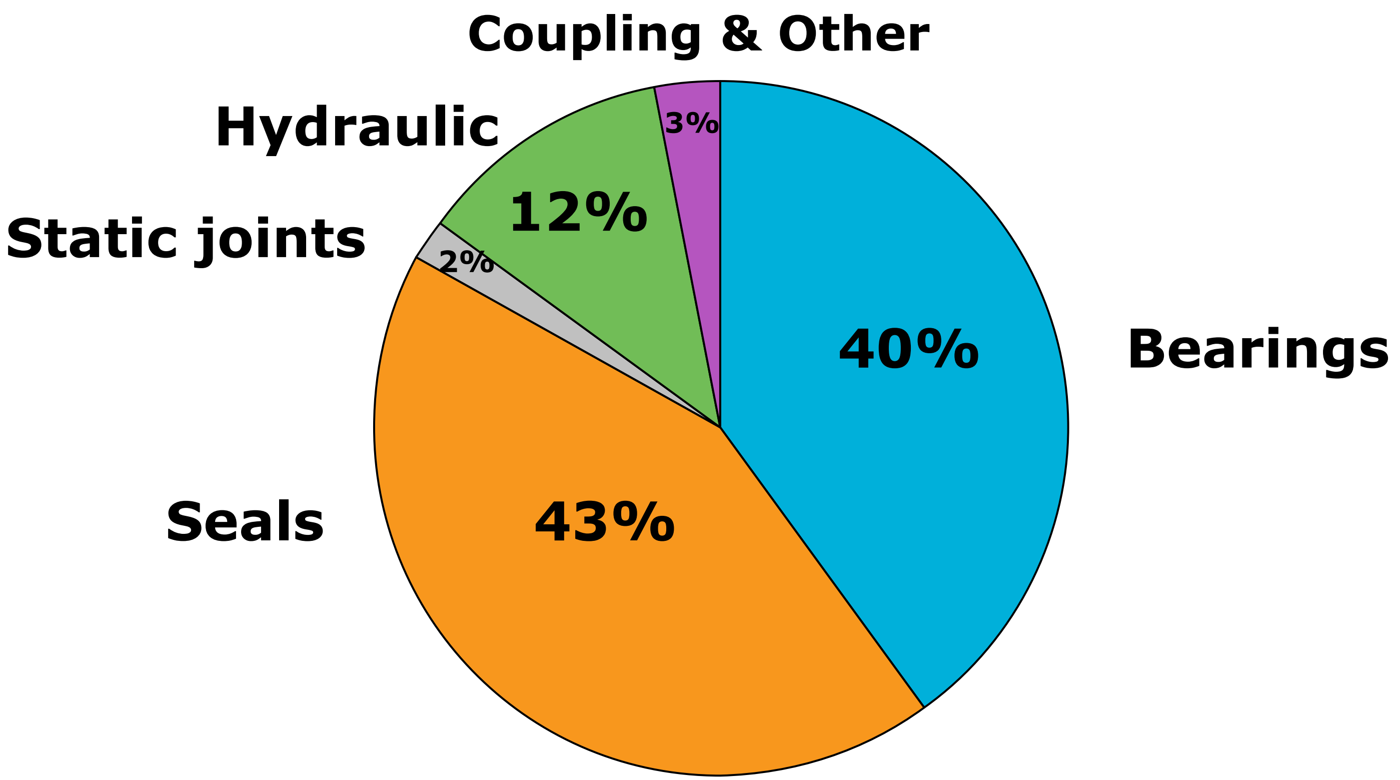
For any power generation facility, the turbine is considered the lifeblood of the operation. Any problem requiring an unexpected shutdown of the main turbine is likely to cause a significant unplanned outage, potentially resulting in millions of dollars of downtime costs. According to a 1991 study by General Electric (GE), turbines contribute on average 20 percent of all forced outages in a conventional power plant. Among this 20 percent, GE noted that 19 percent of turbine/generator problems were associated with the lube oil system. For this reason, monitoring turbine oils has become commonplace in the power generation industry.

http://www.machinerylubrication.com/Read/300/turbine-oil-performance

- 1 out of 5 failures in Turbines is associated with the lube oil system.
- Oil changes cost is less than 5% of total cost of failure!

Reliability and Lubrication. Pumps

Over 80% of pump failures attributed to bearing and seal failures



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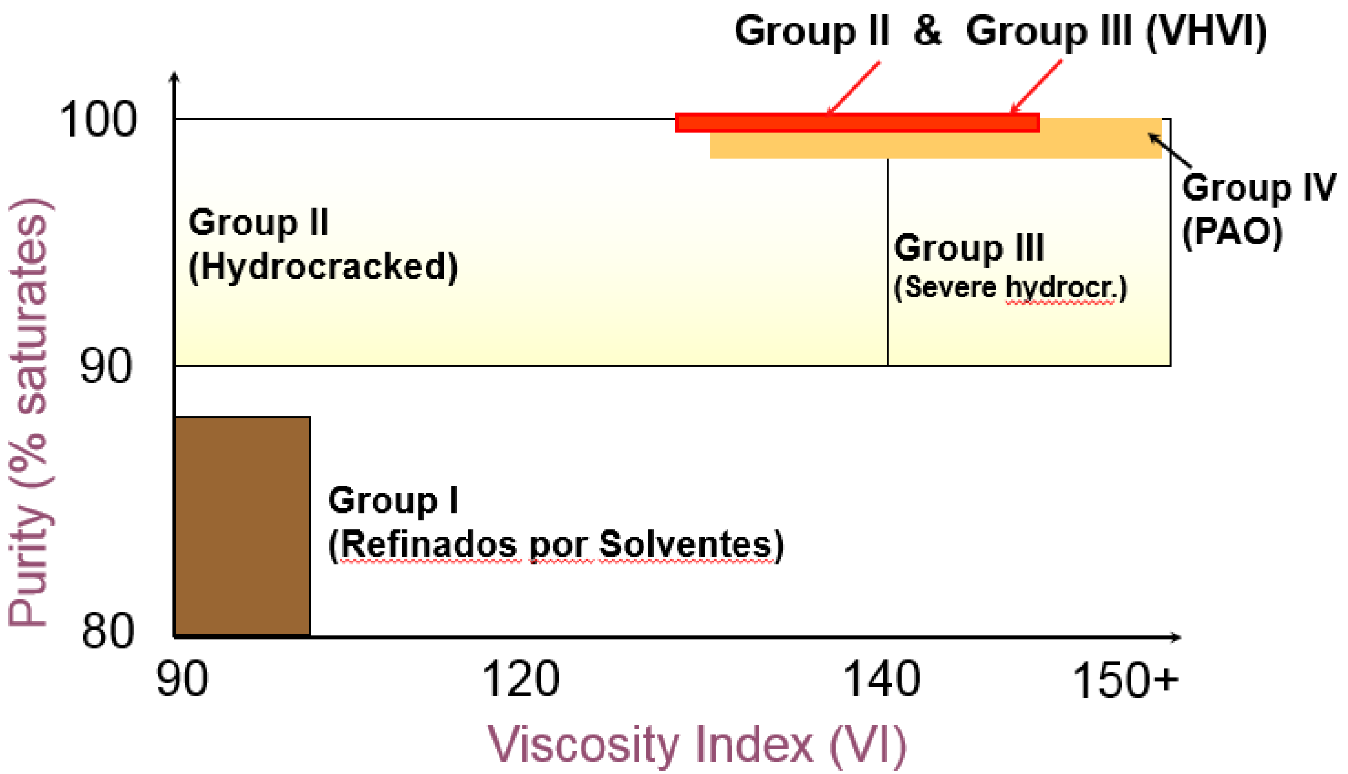
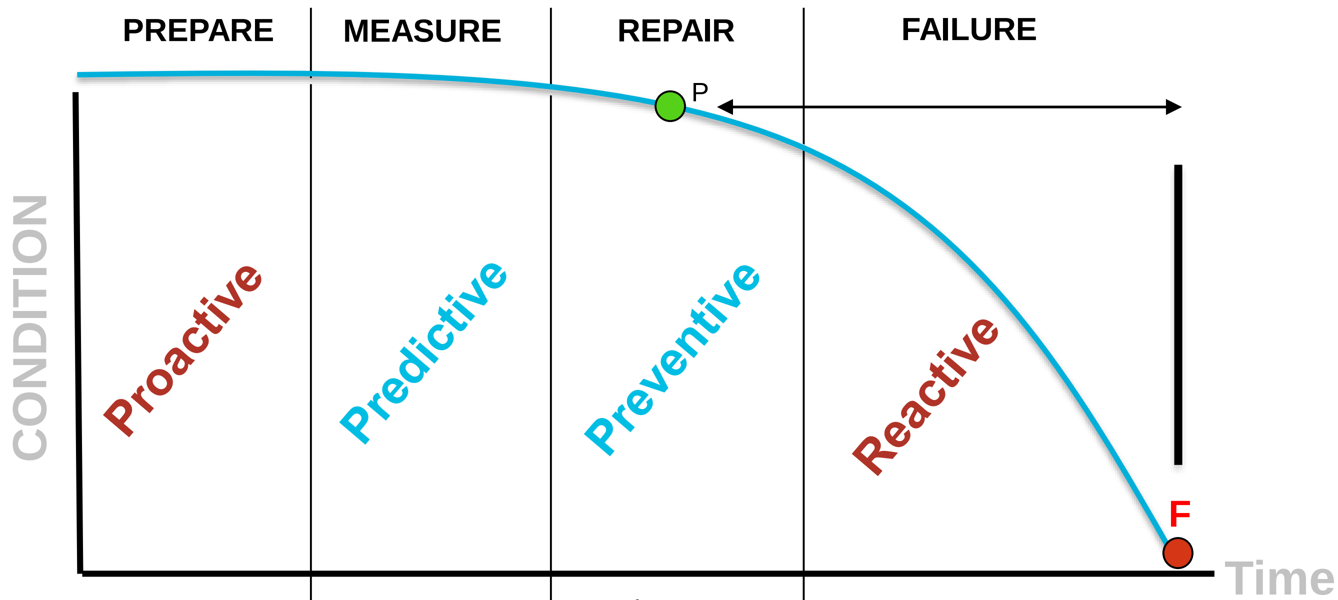
Reliability Strategies

Selecting the right base oil. API Groups



- Resistance to oxidation
- Water and Air Separation
- Thermal stability

The Reliability Opportunity



PREPARE	MEASURE	REPAIR	FAILURE
Oil Mist Lube Oil Systems Grease Systems Lube Room Proactive purification Commiss. Flushings	Oil Analysis Thermography Ultrasound Vibration (Condition based)	Lube Route Filter Changes Oil Changes (Time based)	Emergency Water Removal Particulate purification Varnish Flush HVOF

<u>Preventive & Predictive:</u>
"Sustainable", Everyday activities

Contamination Control Services

Oil Purification

- Increases customer machinery reliability, reducing failure due to poor lubricant condition

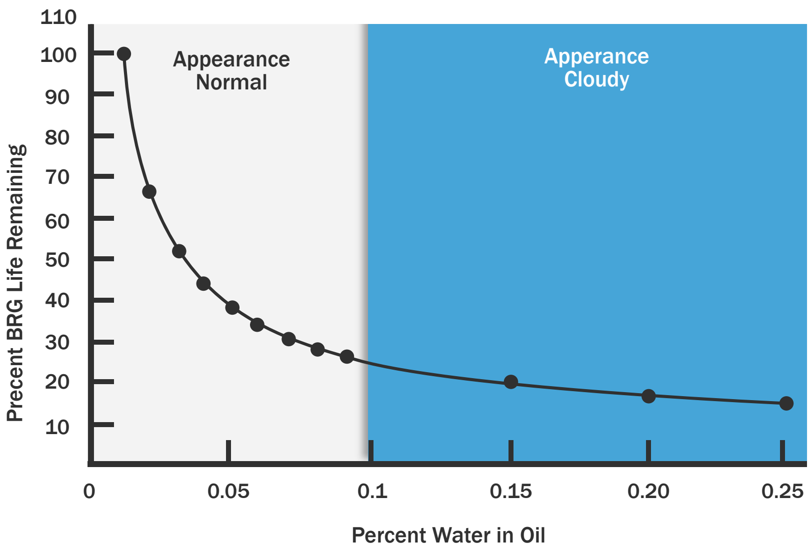
- Eliminates the need for oil changes by maintaining "like-new" oil

- Reduces potential wear and breakdown due to mechanical simplicity and fewer moving parts

- Reduces particle filtration

- Eliminates the need for new oil purchases and reduces oil inventories

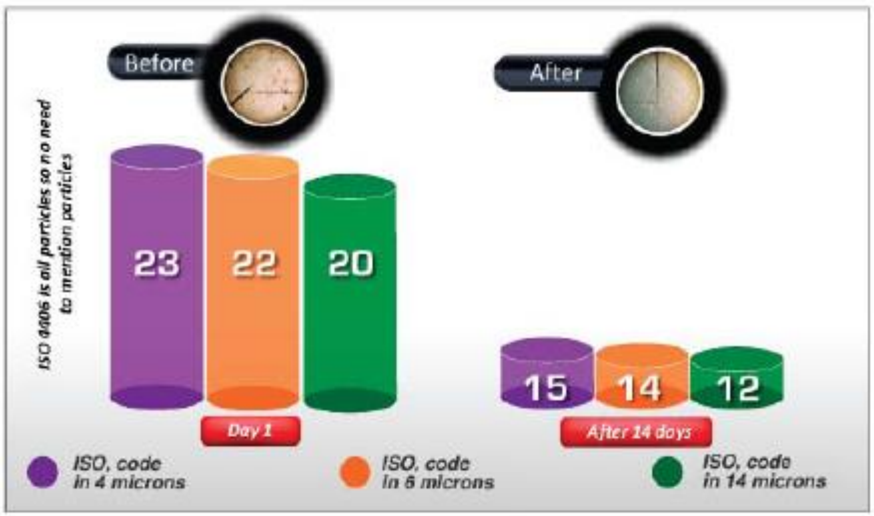
- Minimizes utility requirements; only electrical power required for water removal, or a nitrogen supply for degassing

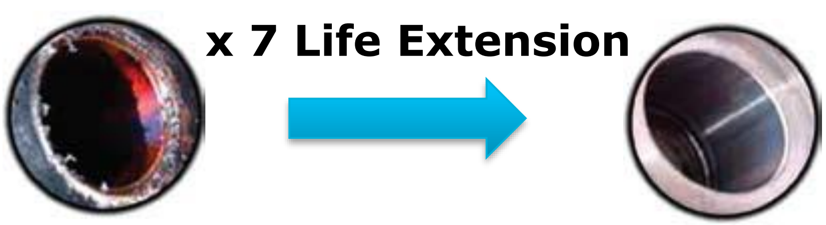


High Speed Oil Flushing Goals

Objectives

Cleaning of Lubrication and Control Systems (High Speed Oil Flushing & Cleaning).®





Reliability: Assure the removal of all particles from the system to reduce risks during equipment start-up and prevent severe premature failure. A higher circulating flow rate in the Flushing and better quality filter elements, result in greater reliability.

Availability: To finish the cleaning in the least possible time, in order to make the equipment available faster and reduce programmed down-time. The Flushing is carried out according to ASTM D-6439-05 standard, which positively impacts the Availability of the Equipment, Increasing Quality Production.

High Speed Oil Flushing Features

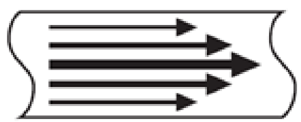
Turbulent Regime → Reynolds Number Re > 4000

Dirt, contamination & deposits on the inner side of the pipe wall

$$Re = 21{,}200 \times Q / (\gamma \times d)$$

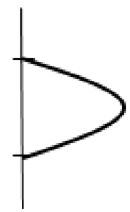
Q – System Flow (l/min)
γ – Kinematic Viscosity (cSt, mm^2/s)
d – System Inner Diameter (mm)

Lube system → Laminar Flow → Reynolds Number Re < 2000



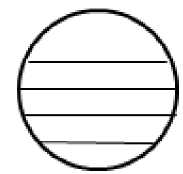
Laminar flow

Re < 2000



Velocity Profile

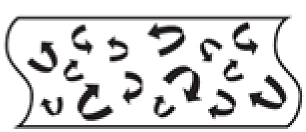
Speed = 0 on inner side of pipe wall



Cross sectional view

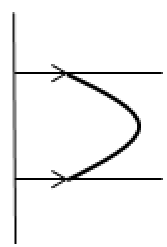
Contact Surface < 100%

External Equipment →Turbulent Flow → Reynolds Number Re >> 4000



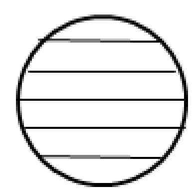
Turbulent flow

Re > 4000



Velocity Profile

Speed > 0 on inner side of pipe wall



Cross sectional view

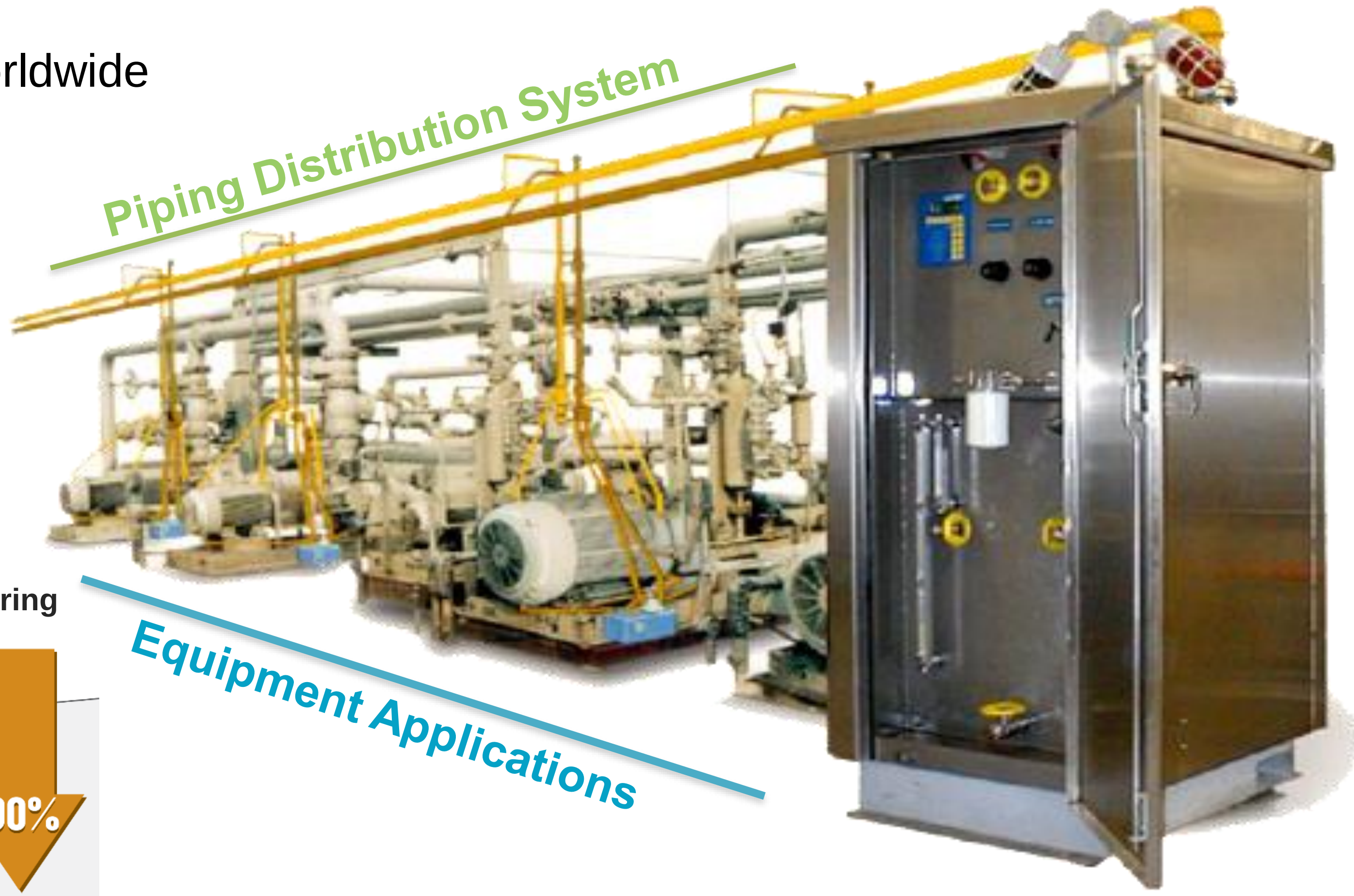
Contact Surface = 100%

Oil Analysis

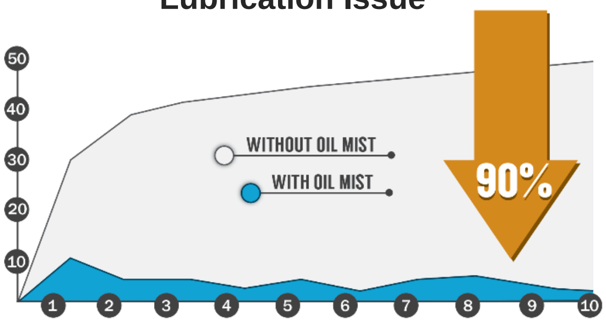
- Select critical equipment
- Select frequency
- Define alarm limits
- Consider sampling points

Oil Mist Systems

> 100,000 pumps worldwide



# of Pump Repairs Due to Bearing Lubrication Issue



Two Similar Olefins Plants, Each with 200 Pumps

Case Studies. Benefits

Case Study. Oil Purification Before Program.

Average conditions of oil lubricant in more than 30 Gas Turbines in Gulf of México.

1. High Varnish Potential due to high presence of particles that causes high temperatures in the oil lubricant.

2. Presence of H_2S from the seal system. This gas contaminates the oil decreasing its viscosity and flash point.

3. High presence of particles. ISO 4406 high values as 23/19/15. **Average. 20/17/12.**

4. Water content average around 250 ppm.

5. Oil lubricant is changed every 3 years average.

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Case Study. Oil Purification After Program.

Average conditions of oil lubricant in more than 30 Gas Turbines in Gulf of México.

1. Low Varnish Potential in the oil lubricant. Temperatures of bearings have decreased 5 ° C.

2. Lower presence of gases. Flash Point at normal values.

3. Lower presence of particles. **Average. 16/14/11.**

4. Water content average around 50 ppm.

5. Oil Change frequency extended.

Oil Purification Benefits

Ítem	Before	After	Result
Oil Change Frequency	Around 3-5 years	Estimated 5-10 years	Savings in 10 kUSD/year/turbine
Varnish Potential	Medium-High	Low	Increased reliability
Gas Present	Medium-High	Low	Increased reliability and safety
Particle Count (ISO)	High 20/17/12	Low 16/14/11	Increased bearing life x 1.8
Water Content	Low 250 ppm	Very Low 50 ppm	Increased bearing life x 1.6

Estimated viable improvements

Oil Purification. Estimated Oil Savings

1	Reservoir capacity	Lts 5.000
2	Hourly manpower costs	30 €/h
3	Oil cost per litre (direct and indirect)	3 Lt/h
4	Yearly oil changes without Purifier	1
5	Yearly oil changes with Purifier	0,20
6	Disposable oil (48 weeks, 70 Lts/wk)	Lts 3.360
7	Manpower dedicated to drain (48 weeks, 5h/week)	240 h
8	Manpower for a proper oil change	20 h
9	Oil Savings thanks to Purifier (A1*(A4-A5)+A6)	Lts 7.360
10	Oil Savings (A9*A3)	€ 22.80
11	Manpower Savings (A2*A7+A8*(A4-A5))	€ 7.216
12	Oil related Total Savings (A10+A11)	€ 29.296

Oil purification. Filter savings

1	Filter changes without Purifier (3 times a year)	3/yr
2	Filter changes with Purifier (once every 2 years)	0,5/yr
3	Manpower cost for filter changes	€ 800
4	Savings for filter changes (B3*(B1-B2))	€ 2.000

Oil purification. Repairs savings

1	Important repairs without Purifier (once/3yr)	0,33/yr
2	Important repairs with Purifier (once/5yr)	0,2/yr
3	Dedicated manpower (including inspection, calibration…)	300 h
4	Important reparis manpower costs (C3*A2)	€ 9.000
5	Spare parts per repair	€ 10.000
6	Production loss per outage day	€ 100.000
7	Manpower savings for repairs (C4*(C1-C2))	€ 1.200
8	Spare parts savings (C5*(C1-C2))	€ 1.333
9	Production loss savings (C6*(C1-C2))	€ 13.333
10	Total savings for better reliability (C7+C8+C9)	€ 15.867

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Oil Purification. Total savings

A – Oil Savings	€ 29.296
B – Filter element savings	€ 2.000
C – Repair savings	€ 15.867

Yearly benefit € 47.163

Flushing Benefits. Allocating costs

Define three types of failure that might occur during the start-up of a turbine following scheduled maintenance

a. **Minor failure**. The post start-up check finds blocked filters, which must be replaced during the first two weeks.
   Cost of 10,000 EUR per equipment item.

a. **Significant failure**. The post start-up check finds vibrations, resulting in lowered loads for a couple of weeks while controls are carried out.
   Cost of 150,000 EUR

a. **Catastrophic failure**. The post start-up check discovers a bearing interference event resulting in a total outage and the need to change bearings. This results in 3 days of additional maintenance.
   Cost of 3,400,000 EUR

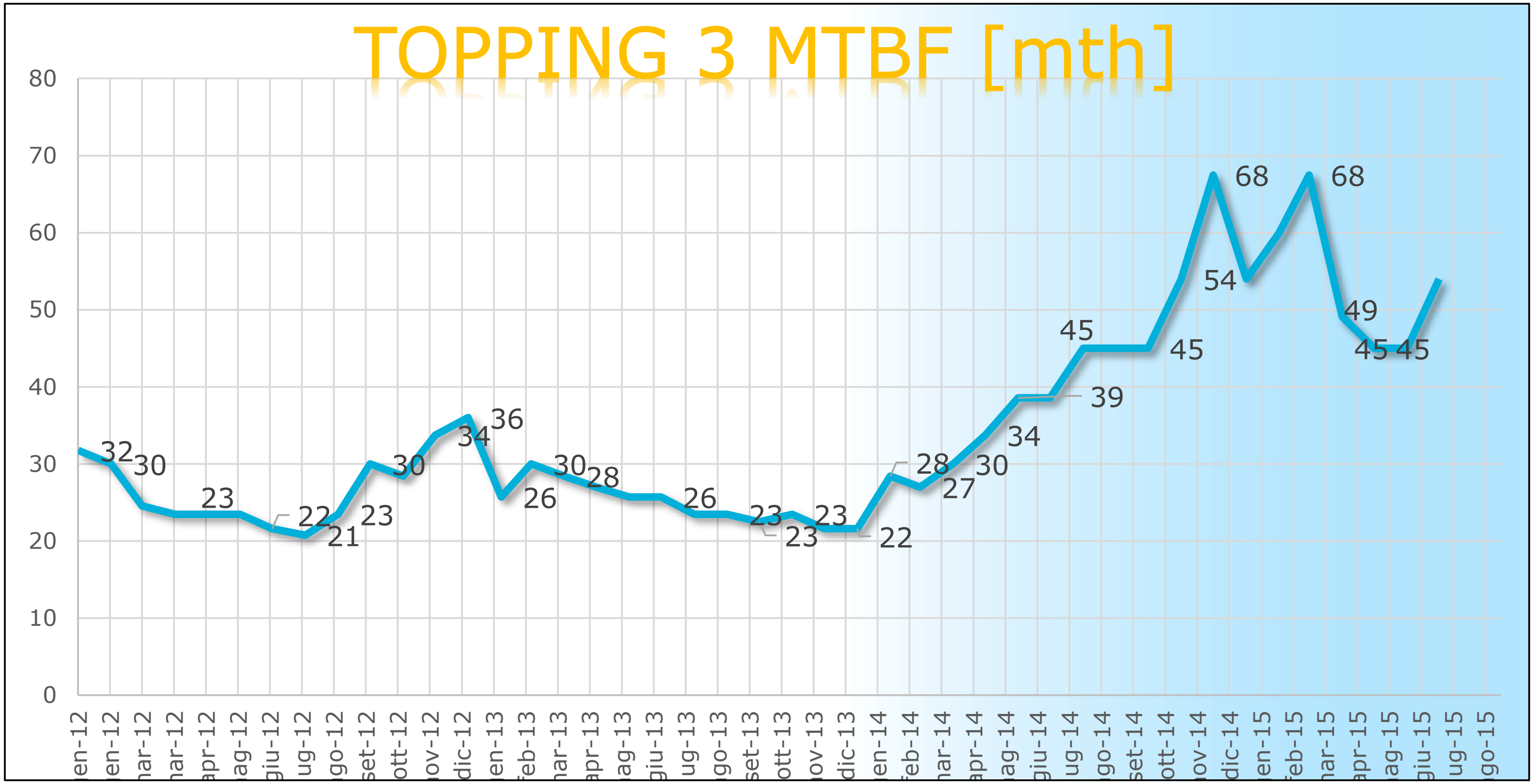
Flushing Benefits. Allocate probabilities

Start-up failure	Conventional Flushing	ASTM Flushing
No failure occurs	45%	60%
Minor failure	40%	30%
Significant failure	10%	8%
Catastrophic failure	5%	2%

Flushing procedure	Cost of Failure
Conventional	10.000x0,4 + 150.000x0,1 + 3.400.000x0,05 = 189.000
ASTM	10.000x0,3 + 150.000x0,08 + 3.400.000x0,02 = 83.000
Benefit	106.000 EUR per item modified

Oil Mist. MTBF Evolution after installation

Increased MBTF for a Topping unit with Oil Mist



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