Bacterial Contamination of Turbine and Circulating Lube Oil Systems:

Detection, Correction, and Prevention

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Abstract:

Bacterial contamination of large circulating oil systems in steam turbines, paper machines and similar systems is a growing and expensive problem. The bacterial colonies, once established, will clog control systems, quickly degrade oil quality and oil performance, and produce corrosive byproducts. If not detected early, the problem will manifest itself into expensive repairs, extended downtime, and a significant expenditure of scarce resources. As the United States steam turbine fleet ages and maintenance intervals are stretched, the problem is growing. Since steam turbines generate approximately 60% of the United States' electrical power demand, the potential problem is significant.

This paper presents a brief description of circulating oil bacterial contamination, problem recognition, types of lubricants and conditions that appear to be most susceptible, methods of treatment, and known methods to clean up and prevent bacterial contamination.

Bacterial Contamination in Oil – What is it?

Bacterial contamination in crude oil and refined petroleum products has been well documented since the 1970's. The problem of bacterial contamination in steam turbine lube oil systems is significant and increasing. Three classifications or types of bacteria are typically encountered in petroleum products:

- Sulfate Reducing Bacteria (SRB) This classification of bacteria metabolizes sulfate and is anaerobic in nature.
- Acid Producing Bacteria (APB) This classification of bacteria ferments sugars to acids (typically light organic acids) and is anaerobic in nature.
- General Aerobic Bacteria (GAB) this classification of bacteria requires oxygen.

These three classification types of bacteria are prevalent in nature. With respect to human health and safety, none of these three bacteria classifications has been tested for human health hazards. It is possible, but not likely, that the GAB classification of bacterium could produce a bacteria strain that might prove pathogenic to a portion of the human population.

These bacteria need the following to survive and grow:

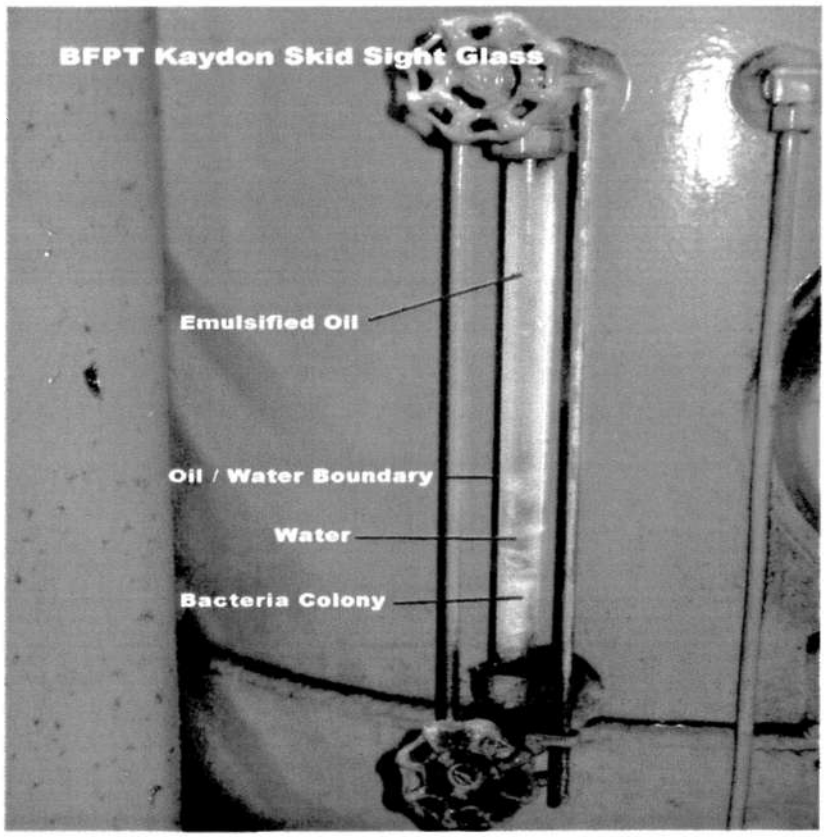
- Water mixed into the oil. 500 ppm is sufficient (.5 ml of water per Liter of turbine oil).
- Organic material (carbon, nitrogen, and phosphorous). Supplied by the turbine lube oil hydrocarbon chains.
- Oxygen. Helps the critters accelerate their growth rates.
- Optimum temperature. (75° to 120° F)

- Stagnant / low flow and dark areas. Turbine lube oil systems abound with these types of protected locations.
- Suspended particulates to serve as initial colonization or coalescing sites.
- Emulsification of the oil to facilitate nutrient transport across the cellular boundary.

If any of the above is disrupted, the bacteria will not grow or survive. Obviously, the easiest environmental factor to influence is the water concentration in the oil.

Bacterial Contamination in Oil – Operational Signs and Symptoms?

Bacterial contamination can only be positively confirmed by laboratory analysis. However, multiple signs and symptoms for operations and maintenance personnel are available. As the bacteria grow, they produce visible colonies of biomass. This biomass has approximately the same color as clear silicone RTV and is gelatinous in appearance. One location where this biomass can be easily viewed is in the sight glass of a Turbo-tac or Kaydon Oil filtration skid.



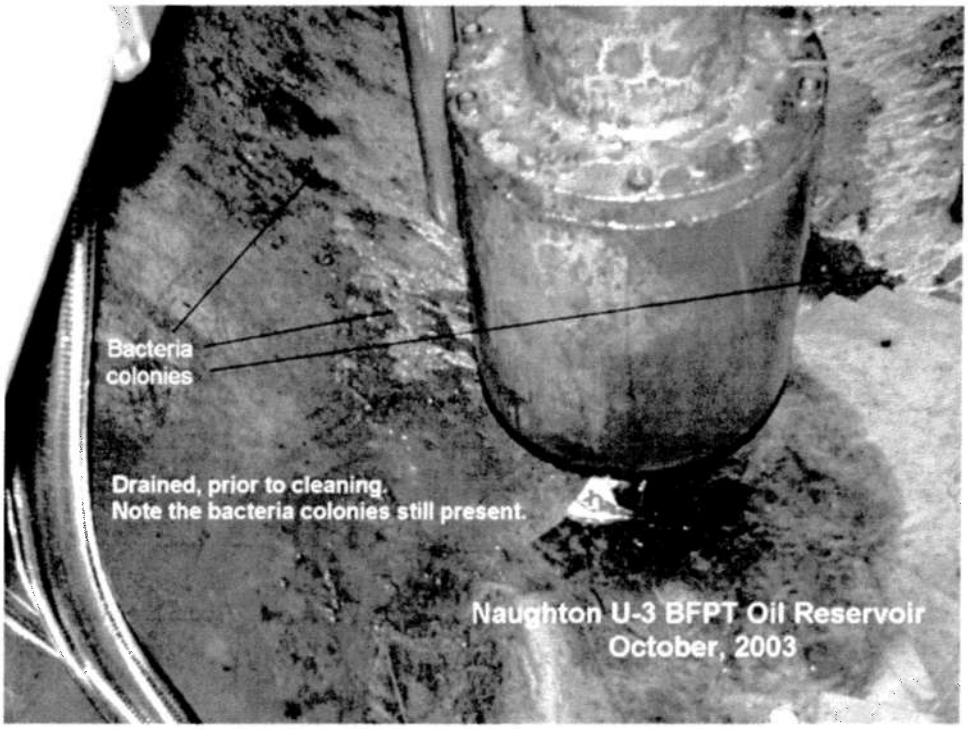
Note the following in the sight glass from top to bottom; emulsified oil, oil water boundary, water layer and bacteria colony. This colony tested to be primarily GAB.

Additional symptoms of bacterial contamination in a turbine lube oil system:

- Frequent plugging of filters with a jelly like substance.
- Sluggish or inadequate controls response – possibly resulting in a unit trip.
- Plugging of control orifices or lines with a gooey, jelly-like substance.
- Prolonged operation with water levels > 500 ml.

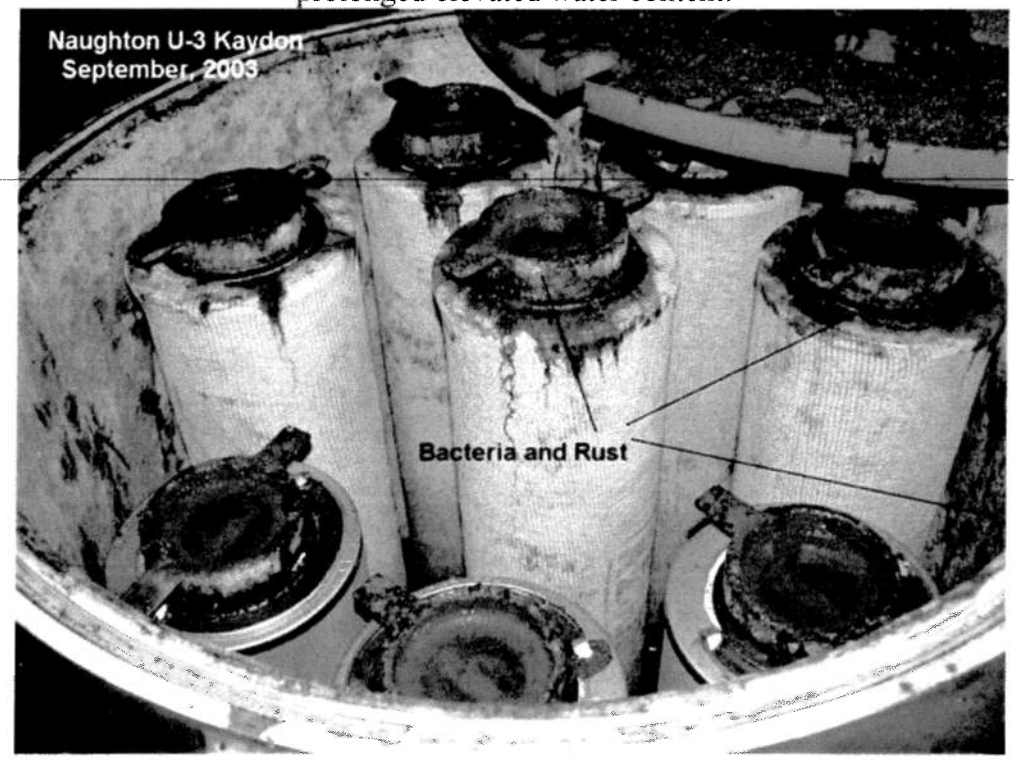
- Emulsified oil or an oily water mixture that will not readily separate.
- Failure of the water demulsification test (ASTM D 1401).
- Failure of the turbine oil foaming characteristics test (ASTM D 892).
- Relatively rapid turbine oil oxidation as measured by the RPVOT test (ASTM D 2272), especially if the oil has not been overheated.
- Isolated, concentrated rust spots on filter elements metal ends, turbine bearing components, etc.

The bacterial contamination may also be visible in the bottom of drained turbine oil reservoirs:



This view was taken looking into a boiler feed pump turbine lube oil reservoir. Note that rust production from the bacteria colonies. The lower right hand corner of the picture shows a cleaned tank surface.

The interior of a Kaydon unit that has been subject to heavy bacterial contamination and turbine oil with prolonged elevated water content:



Bacterial Contamination in Oil – Confirm with Laboratory Analysis

Turbine lube oil bacterial contamination may only be positively confirmed through laboratory analyses. This type of analyses is usually performed by a microbiologist. Most oil analysis laboratories do not have this capability or technical expertise. However, several of the major petroleum producers and refiners do have this type of technical expertise on staff. (Bacterial contamination is a major concern in the pipelines, tank farms, and upstream side. PacifiCorp's lubricant supplier was extremely helpful in this matter.) The microbiological analyses will consist of attempting to incubate and grow colonies in different types of media and then analyzing for biomass activity / RNA / DNA. The laboratory will also attempt to perform activity level counts by the three different classifications of bacteria. It is very important to establish a dialogue with your lubricant supplier / microbiological laboratory to determine the types of samples, preservation requirements, sample locations, etc. is imperative to provide optimal analytical results.

Conditions that Favor Bacterial Colony Growth

The following conditions appear to provide optimal conditions for bacterial colony growth. . . . .

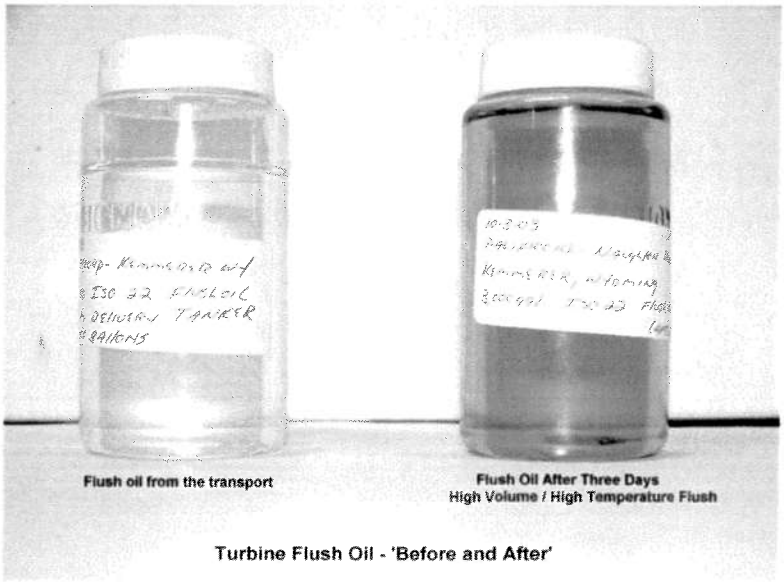
- ***Prolonged water content greater than 500 ppm.*** Water is the necessary medium for the bacteria to live and grow. Even though their food source is the organic material in the turbine lube oil, the water is required.

- ***Relatively constant turbine lube oil temperatures over a prolonged period of time.*** As in food safety, bacteria growth can be inhibited by heating to elevated temperatures or storage at low temperatures.
- ***Group I base stock.*** Group I base stocks tend to support more bacteria growth than Group II base stocks because of their higher aromatics and sulfur content. These compounds tend to tie-up the water in the oil, and promote bacteria growth. Group II base stocks contain paraffins and naphthenes. They are free of aromatics and sulfur. They shed water faster than Group I base stocks, which minimizes bacteria growth, and they remove deposits from metal surfaces, because of their polar nature.

Clean-up and Treatment Methodology

Once bacterial contamination has established itself in the system, eradication can be very difficult. The most effective method involves the following sequential steps:

1. ***Remove the bacterially contaminated oil*** and send it off site for use as fuel oil. It is important that in-plant transfer piping not be used during the removal of the contaminated oil. This will minimize the potential for spreading the problem to other components.
2. ***Inspect and clean the lube oil system.*** This involves disassembly and cleaning of major components. Specific attention should be paid to the reservoirs and filter housings.
3. ***High Volume / high temperature oil flush.*** Utilize a new flush oil (do not use the old oil as flush oil) recommended by your lubricant supplier and perform a high volume / high temperature flush. The oil temperature should be at 160 F minimum and flow rate should exceed 2000 gpm for a 4000 gallon turbine lube oil system. After the flush is complete, dispose of the flush oil as in step 1 above. This flush should also use high quality, full flow filtration capable of at least 3 micron @ Beta>200. A before and after picture of the flush oil illustrates the cleaning that can be accomplished:



Turbine Flush Oil - 'Before and After'

4. ***Perform a final inspection and cleaning*** of the reservoir and any other accessible components. Cleaning should follow the lubricant manufacturers instructions – the use of cleaning solvents or detergents is generally not recommended.
5. ***Refill with new oil.*** When refilling utilize new hoses and fill directly to the reservoir from the transport unless the plant transfer piping is known to be clean and free of bacteria. Install new filter elements and place all filtration components in service. Ensure that the new oil is 'dry'' – less than 500 ppm water content.
6. ***Add a recommended biocide to the lube oil.*** Consult with your lubricant manufacturer for the best application. Test the new oil doped to the recommended biocide level to determine baseline data for: RPVOT, Acid No., Demulsification, Foaming, Viscosity, ASTM Color.

At this point some very important "do's and don'ts":

- ***Do not*** add biocide to the oil without performing any of the other activities. The biocide will kill the bacteria and release a tremendous biomass that will plug filters, control lines, etc. The plugging may be so complete that removal by flushing will be almost impossible.
- ***Do*** add biocide to the oil when the system is operational and after the system has been thoroughly cleaned, flushed and filled with new oil. Read and follow all precautions.
- ***Do not*** use the lowest oil flush contractor to perform the high volume / high temperature flush.
- ***Do*** use an oil flush contractor that has state-of-the-art, engineered, high volume pumping and filtration equipment. During the flushing process it is important the biomass and other contaminants that the bacteria live on are kept in suspension and captured by the filtration equipment.
- ***Do*** write a detailed specification and contractual document for the high volume / high temperature flush.
- ***Do not*** cross contaminate other plant systems with bacterially infected oil. Think contamination control – utilize your microbiologist / laboratory to provide basic instructions in this concept.
- ***Do*** assume that other plant lubrication systems are contaminated with bacteria and treat with biocide. Ensure that the biocide is compatible with these oil types.

Prevention of Bacterial Contamination:

Prevention of lube oil bacterial contamination is relatively simple and straight forward:

<u>Keep the water in the oil to less than 500 PPM.</u>

Other factors that will help prevent bacterial contamination:

- Utilize turbine oil / circulating oil formulated from Group II Base Stock.
- Minimize the formation of stagnant water, i.e. in separator sight glasses.
- Maximize filtration, maintain low ISO Particle Counts. The bacteria need water to grow but they also need a coalescing site to start their colonies.
- Perform daily 'clear and bright' inspections.
- Maintain an appropriate biocide dosage level if bacterial contamination has been identified and subsequently cleaned.

Acknowledgements:

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