



Fluid Analysis 101



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FLUIDS TESTING 101

This is a general overview of in-service fluids testing for equipment reliability and lubrication management which provides some basic guidelines and information. This information does not cover all technical aspects or application of a successful fluids analysis program. ALS as a partner in achieving optimal return on investment with your asset maintenance and dependability activities, related to fluids analysis, is available to provide additional assistance.

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Tests Descriptions

1.1 Tests Descriptions - Fluid Condition and Properties:

Spectrochemical Analysis for Additives:

The spectrochemical analysis measures different metals in parts per million (ppm) which represent lubricant additives, as well as system contaminants and equipment wear.

Antimony (Sb): Antiwear and Extreme Pressure, Antioxidant, Corrosion Inhibitor

Barium (Ba): Rust inhibitor, Water separability

Boron (B): Extreme Pressure Additive, Detergency

Calcium (Ca): Detergency, Alkalinity Reserve (contributes to base number)

Magnesium (Mg): Detergency, Alkalinity Reserve (contributes to base number)

Molybdenum (Mo): Extreme Pressure Additive, Lubricity Additive

Phosphorus (P): Antiwear when present with Zinc, Extreme Pressure Additive, Friction modifier

Potassium (K): Extreme Pressure Additive in some gear lubricants **Sodium**

(Na): Corrosion Inhibitor.

Silicon (Si): Anti-Foam Additive

Zinc (Zn): Antiwear when present with Phosphorus, Antioxidant, Anticorrosive.

Viscosity:

Improper viscosity can affect a lubricants performance.

Too low of a viscosity will not create sufficient surface film to keep moving parts separated and prevent rubbing on opposing metal surfaces.

Too high of a viscosity will create excessive heat and reduced fluid flow within circulating systems.

A change in viscosity will indicate a change in the fluid performance integrity. A drop in viscosity generally indicates contamination with a lighter product, addition of an incorrect viscosity grade, and in some cases thermal cracking. An increase in viscosity can indicate oxidation and reduced service life due to age, addition of an incorrect viscosity grade, or excessive soot or insolubles content.

Base Number:

Base number represents the level of alkalinity reserve available for neutralizing acids formed during the combustion process and may be introduced through recirculated exhaust gases. As the lubricant ages and the additive package depletes, the base number will decrease from its initial fresh oil value.

Acid Number:

Acid number in a new lubricant represents a certain level of additive compounding. This can come from antirust, antiwear or other additives. The acid number can drop a bit after a lubricant has



been in service for a certain period, which indicates some initial additive depletion. After a time the acid number will start to increase, which indicates the creation of acidic degradation products related to oxidation. The acid number is a means of monitoring fluid service life.

Oxidation Number:

The oxidation number is a relative number that monitors increase in the overall oxidation of the lubricant by infrared spectroscopy. This test parameter generally compliments other tests for fluid service life, such as viscosity and acid number. Generally this test is not used as a primary indicator when all other tests are within normal limits. Accurate oil information is required to get the most valid test results.

Nitration Number:

The nitration number is a form of oxidation that relates to chemical reaction with nitrogen, forming nitrogenous compounds also. Nitration is a relative number that monitors increase in the overall fluid degradation due to reaction with nitrogen and oxygen by infrared spectroscopy. This test parameter generally compliments other tests for fluid service life, such as viscosity and acid number. Generally this test is not used as a primary indicator when all other tests are within normal limits. Accurate oil information is required to get the most valid test results. Contributors to increased nitration can come from exhaust gas blow-by or reaction with natural gas products with the lubricant and heat. It is also an indicator of electrostatic discharge across filter surfaces in turbine oil.

Sulphation Number:

The sulphation number is a form of oxidation that relates to chemical reaction with sulfur compounds also. Sulphation is a relative number that monitors increase in the overall fluid degradation due to reaction with sulfur compounds and oxygen by infrared spectroscopy. This test parameter generally compliments other tests for fluid service life, such as viscosity and base number. Generally this test is not used as a primary indicator when all other tests are within normal limits. Accurate oil information is required to get the most valid test results. Increase in sulphation generally correlates to a decrease in base number.



1.2 Tests Descriptions – Contamination:

Spectrochemical Analysis for Contaminants:

The spectrochemical analysis measures different metals in parts per million (ppm) which represent contaminants, as well as equipment wear and lubricant additives.

Aluminium/Aluminum (Al): After-cooler Brazing Flux, Dirt if in combination with Silicon

Boron (B): Engine Coolant

Magnesium (Mg): Seawater if present with sodium

Potassium (K): Engine Coolant, After-cooler Brazing Flux

Silicon (Si): Dirt (especially in combination with aluminium/aluminum and/or sodium), Gasket/Sealant Material, Engine Coolant

Sodium (Na): Engine Coolant, Seawater, by product from Natural gas (wet gas) transferring, Dirt in combination with silicon, Road Salts

Water:

Water as a contaminant will generally lead to increased corrosion, depletion of proper lubricating film, decreased lubricant performance life and increased acid formation.

Coolant:

Coolant contamination will degrade lubricant service life and performance, create sludge and block lubricant passageways.

Fuel Dilution:

Fuel dilution will decrease fluids viscosity, therefore affecting its lubricity properties. Fuel dilution also promotes degradation of lubricant service life and additive properties.

Soot:

Excessive soot increases viscosity, creates excessive wear, and will tie up active additives needed for lubricant performance.

Particle Count:

“Clean Systems” require a minimum level of cleanliness in order to operate reliably. This is especially true for circulating systems with high pressure and close tolerance components. The ISO Cleanliness Rating is a convenient way to communicate the level of particulate contamination within a system based on the particle count for micron sizes greater than 4, 6, and 14.

1.3 Tests Descriptions – Wear Metals and Wear Debris:

Spectrochemical Analysis for Wear Metals:

The spectrochemical analysis measures different metals in parts per million (ppm) which represent equipment wear, as well as system contaminants and lubricant additives.

Note: The listing below illustrates some major sources of wear metals but does not indicate all possible secondary sources. Abnormal wear is commonly indicated by a combination of metals.

Iron (Fe): Major component material in equipment manufacturing. Housing/Blocks, Cylinders, Pistons, Gears, Bushings, Bearing, Shafts, Valves, Rings, Rust

Chromium (Cr): Cylinders Liners and Guides, Bushings, Bearing, Shafts, Valve, Rods, Rings, Hydraulic Cylinders



Lead (Pb): Bearings/Bushings, Thrust Plates, Washers

Copper (Cu): Bearings/Bushings, Thrust Plates, Washers, Oil Cooler, Pumps, Disc/Disc Lining.

Tin (Sn): Bearings/Bushings, Pumps, Motors, Compressor Piston, Piston skirt overlay

Aluminium/Aluminum (Al): Pistons, Bearings/Bushings, Thrust Washers, Rings, Housing/Blocks, Oil Cooler, Cylinders and Cylinders Guides, Engine After-cooler

Nickel (Ni): Gears, Shafts, Rings, Valve Trains, Bearings/Bushings, Pumps

Silver (Ag): Bearings/Bushings, Oil Cooler, Some Gears and Shafts, Disc/Disc Lining

Titanium (Ti): Bearings/Bushings, Some Gears and Shafts, Turbine Blades, Valve Trains, Gear Trains, Some Shafts (additive in some HDMO's)

Vanadium (V): Turbine Blades, Some Bearings and Bushings,

PQI:

PQI is a valuable trending tool for monitoring the relative level of ferrous wear material within a lubricant sample.

Filter Patch:

Filter patch inspection provides a visual assessment of wear particle and other solid debris present in a sample after collection on a 0.8 micron to 5.0 micron filter membrane and examined by a microscope.

Analytical Ferrography:

Analytical Ferrography provides detailed information on different wear particles present in a sample. This is generally an exception test that provides information on the type of metal makeup of the wear particles present and how they were formed.



Starting and Managing an Analysis Program

2.1 Starting and Managing an Analysis Program - Determining Goals and Measurables

When establishing an in-service lubricant analysis program goals and targets should be established that provide your most effective return on investment. The three main areas that goals generally fall into are:

- Equipment management
- Lubrication management
- Maintenance management

Goals can consist of many categories, which include but may not be limited to: **Equipment Management**

- Increase equipment reliability
- Extended equipment life
- Increased production efficiency
- Increase equipment resale value

Lubrication Management

- Lubrication cost savings
- Optimal oil drain Intervals (optimal drain intervals does not always relate to extended drain interval)
- Consolidate product inventory
- Transition to new product formulations

Maintenance Management

- Reduced maintenance cost
- Avoid catastrophic failure
- Reduce downtime
- Provide backup for warranty claims
- Schedule maintenance more effectively

As goals are determined measures should be established to accurately track progress towards these goals and demonstrate a return on investment.



2.2 Starting and Managing an Analysis Program - Equipment Selection

When starting or expanding an in-service lubricants analysis program the selection of equipment should be such that the execution of the program is manageable and organized.

When getting started with implementing analysis of in-service lubricants many times equipment owner/operators and maintenance personnel wonder which equipment would be relevant to the benefits of trending analysis. The short answer is anytime there is a substantial capital investment in equipment or if the equipment is a critical component to the business operation. When selecting candidates for an analysis program here are a few options to consider:

Do not take on too much at once:

When getting started, focus on equipment of particular interest and do not feel every piece of machinery has to be brought on board at the same time. This will allow an opportunity to fine tune internal processes for submitting samples to the laboratory, verify the selected test package is applicable, and ensures a process for following up on test reports and data is provided. Sometimes it makes sense to focus on the more problematic areas initially and build the program from there.

Equipment age:

Newer and older machinery usually need more frequent sampling frequencies and experience more frequent service issue than established equipment not undergoing extended service life. Work environment.

Machinery exposed to more severe environmental conditions, such as dirt, moisture, temperature extremes, and harsher duty cycles are candidates for close monitoring of in-service lubricants and coolants through trending analysis. This is also a factor in sampling frequencies.

Penalty of failure:

Assess the penalty of failure to the operation if a particular piece of equipment goes down. How much capital is invested in the equipment? What is the cost to the overall operation if machinery is not operating? How much is bottom line affected due to unplanned downtime, as opposed to scheduled downtime?

Sump size is not the total picture:

Many times it is thought that due to a small sump size it's easier to just change the oil than worry about taking a sample. After all, "oil is cheap", and by the time the trouble is taken just to get a sample, the oil may as well have been changed any way. What should be considered in these circumstances is that oil analysis looks at two facets. Both the condition of the equipment and the condition of the lubricant in service. What can that sample tell us about the condition of the equipment? Is the machinery critical to the overall operation? If so, wear patterns should be monitored. Are there contaminants that contribute to undue wear such as dirt and water? Is the equipment running under excessive heat that contributes to severe service duty and compromises the integrity of the lubricant?

Assess the equipment that will receive routine testing.

Assess penalty of failure

- Critical to operation
- Downtime and repair costs
- General cost to business interruption



Severity of fluid environment

- Contamination ingress
- Loads, speed, and temperature
- System duty cycle severity

Other factors

- Machine age (old and new)
- Machine reliability and service record
- Oil age

When starting up or expanding an analysis program for equipment in-service lubricants ALS is available to assist in equipment selection and the appropriate test packages. We can work with both your lubricants supplier and maintenance staff.

2.3 Starting and Managing an Analysis Program - Selecting the Proper Test Package

Selection of an applicable in-service test package for equipment should be in line with goals and target that have been established that contribute to measurables that track return on investment.

The test package should be also cost effective. Do not pay for extra testing if it is not providing usable data. Test packages that do not provide the right information of insufficient data are also not cost effective.

An effective test package should accomplish the following:

- Monitor health of equipment
- Monitor health of fluid
- Complement other maintenance practices
- Establish root cause limits
- Establish predictive maintenance practices
- Cost effective

2.4 Starting and Managing an Analysis Program – Establish Ownership

Establishment of ownership of the testing program by the end-user is very important. The optimizing benefits and equipment reliability requires timely sampling, sample submission, follow up of the data, and tracking successes.

The end-user should have a point person that can establish that critical partnership with the testing laboratory and lubricant supplier.



Sampling

There are a variety of manners in which an in-service oil sample can be obtained. Many times, choices are based on the availability of access points. Sampling can often be made easier and expedited with improved safety by installing sampling ports in strategic locations. Some equipment manufacturers provide factory installed sampling ports.

The best sampling point may not always be the most practical. In this case, the most important factor when considering a sampling location is consistency, which greatly affects the quality of the historical data in trending analysis. Below are sampling practices that may be employed for some common systems.

3.1 Sampling – Establish Testing Frequencies

Initially sampling frequencies may start out conservatively until a history is developed on a particular piece of equipment. It is common to sample during oil drains, which works well in many circumstances, but if the equipment has extended drain intervals equipment problems with wear or contaminants may go unchecked for too long.

Initial sampling frequencies can be established based on criteria listed below along with guidance from ALS. Sample intervals should be tailored to the operation.

- Machine age
- Machine reliability and service record
- Oil age
- Application
- Duty cycle
- Work environment

3.2 Sampling – Best Practices

- Establish consistent procedures
- Determine optimal sampling points that provide the best information.
- Ensure safe sample extraction methods
- Minimize sources of garbage data due to sampling location
- Fill out required sample information
- Establish procedures for forwarding samples to the laboratory, send in right away.

3.3 Sampling - In-line Sampling from a Circulating System

Using a permanently installed sampling valve, such as the 1/8" NPT Push Button Valve, helps produce reliable test results. This valve must be properly mounted on an oil line facing downward. The installed sampling valve will also facilitate the sampling process.

- Make sure the oil is flowing and warm.
- Avoid sampling in dead flow areas where contaminants may settle.
- Areas with turbulent flow are best, such as bends.
- Return line sample locations after oil has gone through the equipment are best.
- Do not collect samples after the filter or directly from the filter.



- Flush port areas.
- Use new tubing.
- Use as little tubing as possible.
- Use pump in low flow or low pressure areas.
- Clean area around sampling port.
- Collect sample directly into sample bottle, do not transfer from intermediate container.
- Do not use funnels.
- Use extra care for samples requiring a particle count.

In-Line Valve - General Procedure

1. Unscrew dust cap from valve.
2. Depress the button on the valve.
3. Flush the line by allowing a few ounces to drain before taking the sample.
4. Place the empty new sample bottle under the valve discharge opening.
5. Fill the sample bottle $\frac{3}{4}$ full.
6. Tighten the cap on the sample bottle to secure a tight seal.
7. Use certified clean bottles if collecting a sample for particle count from “clean systems.”
8. Screw the dust cap back on the valve.

Possible In-line Sampling Locations

Engine Oil: Filter mount on engine block, before filter inlet *Transmission:*

Filter head, before filter inlet.

Hydraulic: Manifold or return lines

Turbine Return lines

Axle: Oil pump

3.4 Sampling – Reservoirs and Sumps

Though in-line samples are optimal, sampling from reservoirs is acceptable. Using a vacuum pump with attached tubing will provide the best sample and facilitate the sampling process.

- Make sure the oil is flowing and warm.
- Sample through breathers or fill ports.
- Clean area around breather or fill port before opening.
- Use new tubing.
- Use as little tubing as possible.
- Do not collect sample from the very top or the very bottom of the fluid level.



- Collect sample from one-half to two-thirds into the height of the fluid level.
- Collect sample as close to the inlet as possible.
- Use new tubing.
- Use as little tubing as possible.
- Collect sample directly into sample bottle; do not transfer from intermediate container.
- Do not use funnels.
- Use extra care for samples requiring a particle count.

3.5 Sampling - During Oil Drain

Acquiring a sample during an oil drain is not as optimal but may be the only method available. Care should be taken to ensure consistent sampling procedures and that samples are obtained in a safe manner.

- Oil should be warmed and recently circulated.
- Do not take sample when the oil has been cold and static.
- Do not take samples immediately after drain flow begins.
- Takes samples at mid-drain.
- Do not use a funnel.
- Do not empty oil and take the sample from a drain collection container.
- Clean bottle off before shipping.
- The accuracy of the oil analysis depends on the quality of the information provided to the laboratory.



Sample Submission

4.1 Sample Submission - General

Do not fill samples completely to the top. Leave room for volume expansion while the sample is in route. Ensure lids are closed tightly and do not leak.

The accuracy of the oil analysis depends on the quality of the information provided to the laboratory. The information that is provided during sample submission on a Sample Information Form (SIF) is divided into two areas; First time samples from equipment and repeat samples from existing equipment.

First time samples on equipment require more information regarding the unit identification make/model, serial number, etc.

Repeat samples on existing equipment do not require all information on a submission form once the unit has been established in the systems. Repeat samples on existing equipment only require information that is unique to that particular sample such as sample date, time on fluid, time on unit, etc.

The Sample Information Forms provided by ALS are two sided. One side is relevant to first time samples on a piece of equipment, or updating equipment information. The second side of the Sample Information Form is for repeat samples on existing equipment.

The easiest way to identify an existing piece of equipment that has been established in the system is by the UIN number. This number is an internal ALS number that easily identifies your equipment and is displayed on test reports.

There should be an internal procedure established for sending sample to the testing laboratory. If samples are not sent to the lab as soon as possible there is a risk that the data will not be timely and relevant, or equipment reliability problems will not be flagged in time. It is best that there is ownership by the enduser for ensuring samples are submitted and data is received responsibly.

Use a reliable means for delivering samples to the laboratory for testing. Mailing samples is not the most reliable means. If mailing samples ensure there is adequate postage. A commercial deliver service, such as UPS or FedEx that provides tracking of sample delivery is recommend and is generally less expensive than mailing a sample if several samples are being shipped.

4.2 Sample Submission – Equipment Information

- Equipment identification ○
 - Consistency, very important
- Makes and models
- Equipment description ○
 - Gearbox, turbine, engine, hydraulic, etc.
- Oil type ○
 - Brand and type ○
 - Accurate information ○
 - Changes in oil information
- UNI Number!
 - Takes care of all unit information if nothing has changed



4.3 Sample Submission – Sample Information, Unique to Each Sample

- Sample date
- Time or kilometers/miles on equipment
- Time or kilometers/miles on oil
- Filter information
- Oil added or changed

4.4 Sample Submission – Other Information

- Required testing if not already established
- Rebuilt/recent maintenance
- Special problems or issues
- Contact to which additional copies will be sent

4.5 Sample Submission – Online Sample Submission by Barcoding

Creating sample submission labels simplifies the sample submission process and improves accuracy. Barcoded Avery labels can be created via ALS's WebTrieve Website. ALS clients services and account managers can assist with coaching customer how to create bar coded sample submission labels.

- Accessible through WebTrieve
- Prints on adhesive labels
- Reduces time in filling out forms
- Increases accuracy

4.6 Sample Submission – Sample Submission Using ALS Mobile App

Online Sample Entry using the ALS Mobile App allows users to submit information about samples that will be sent to ALS for analysis while the sample is being prepared. This feature allows a user to submit sample information to ALS from the mobile app, much the same way they can submit sample information with the full Webtrieve™ Website



Receiving Your Test Report

Establishing ownership of the test reports and equipment reliability data is instrumental in optimizing equipment reliability through a fluids analysis program. Assigning ownership of management of the reporting, data, and coordinating with reliability/maintenance staff and the laboratory will ensure return on investment is also optimized.

5.1 Receiving Your Test Report – Receipt Ownership

There are a variety of means to obtain test reports once a sample analysis is completed. Though hard copies are available the best means of receipt is electronic. Electronic receipt is available through ALS's WebTrieve website, emails with PDF attachments, and through the Mobile App.

Sample notification can also be provided through a web application.

- Notifications can be limited to sample condition, which includes Normal, Caution, Abnormal, and Severe.
- Caution severity is intended to provide an alert to that a situation should be monitored.
- Abnormal severity ratings indicate that some level of corrective action is required which should be addressed in a timely and cost effective manner.
- A Severe rating alerts personnel that immediate corrective action is necessary and continued equipment or fluid reliability has been compromised.

Online reporting provides easy access to test reports, real time data receipt, creation of management reports, saving, and forwarding reports to individuals.

There should be an established internal procedure for report receipt by the end user that ensures the information gets to the right person that is responsible for equipment, lubrication practices and data management. There should be a key individual that is able to coordinate testing services with the laboratory.

5.2 Receiving Your Test Report – Reading Your Test Report

There are five key areas that provide the elements of a test report:

- Equipment Information and Client Information
- Sample Information
- Test Results with Histories
- Diagnostics
- Trending Graphs

Equipment and Client Information

Equipment is displayed on the report that represents equipment owner, work location, manufacturer make/model, serial number and sump capacity. This information is displayed for the compartment as well as the overall equipment if relevant. This information would not generally change from sample to sample. Also included in this section is the ALS UIN for easy tracking purposes of the equipment within the system

Sample Information

Sample information appears at the top of the report. This information changes from sample to sample depending on the information provided when the sample was submitted or lubricant in service has changed. This area will show information regarding the following:



- Date Sampled
- Date Tested
- Date Reported
- Lab internal tracking number
- Sample information form tracking number
- Length of time (kilometers /miles/hours) the compartment has been in service, since new or rebuild
- Length of time (kilometers / miles/hours) oil has been in service
- Lube brand (manufacturer)
- Lube product name
- Lube product viscosity (SAE/ISO)
- Fluid added between samples or changes
- Was the oil filter changed
- Was the lube oil changed
- Work Order number assigned to the PM

Test Results

Test results represent the condition of the equipment as well as the condition of the fluid in service. Histories of previous samples are provided on the test reports that provide a picture of the wear patterns, contaminant levels, and fluid properties over time.

Problems are identified and highlighted specific to test results which contribute to the overall health of the equipment and fluid in service. Past problems highlighted by test results are trended to provide the historical health and condition of the equipment.

Diagnostics

The diagnostics section provides a summary of the equipment and fluid condition in written text. This summary takes into account the equipment information, sample information, test results, and historical trending data. The diagnostics summary provides commentary on wear, contaminants, and fluid condition intended to compliment other maintenance and reliability practices, and lubrication management practices.

Flagging a test result whether for a warning or condemning notification generally requires assessment of multiple factors associated with the sample that was tested.

Condemning limits for wear are not always based on absolute limits on sample test results since there is so much that goes into evaluating the wear pattern of different types of equipment or equipment applications. Having an absolute wear metal limit (such as iron levels in a gearbox) is just a starting point. Different makes and models for similar types of equipment can have unique wear metal limits; this is also affected by work environment and the age of the lubricant in service.

Many times our diagnosticians will not wait for a single test result to reach a condemning limit before indicating a problem on a test report. An accelerated increase or rate of change from the previous sample for a test parameter, such as acid number or viscosity, for the time on the oil can raise a warning flag. There are also situations where a combination of test results are heading in a detrimental direction, yet no single test results has reached a condemning limit on its own. Generally the diagnosticians try to look at a combination of parameters, both related to the oil and equipment information, as well as a matrix of test results

Trending Graphs

Test reports provide trending graphs that visually demonstrate changes over time of key parameters



Follow Up

Follow up is key to maximizing equipment reliability through a successful fluids analysis program. This is where many efforts fall short. Once the data is available what does the end-user do with it?

6.1 Follow Up - Ownership of Data

Without an established internal process for ownership of the data much of the time this information is not used effectively or sometimes not at all. There should be someone who is responsible for ensuring data is managed in such a way that return on investment and equipment reliability is optimized. This includes coordinating follow up with the testing laboratory, updating equipment information, coordinating corrective action and tracking return on investment.

- Who takes ownership of fleet data?
- Are roles clearly defined
- Partner with key stakeholders
 - Testing laboratory
 - Lubricant supplier
 - Operations management
 - Maintenance staff

6.2 Follow Up - Corrective Action

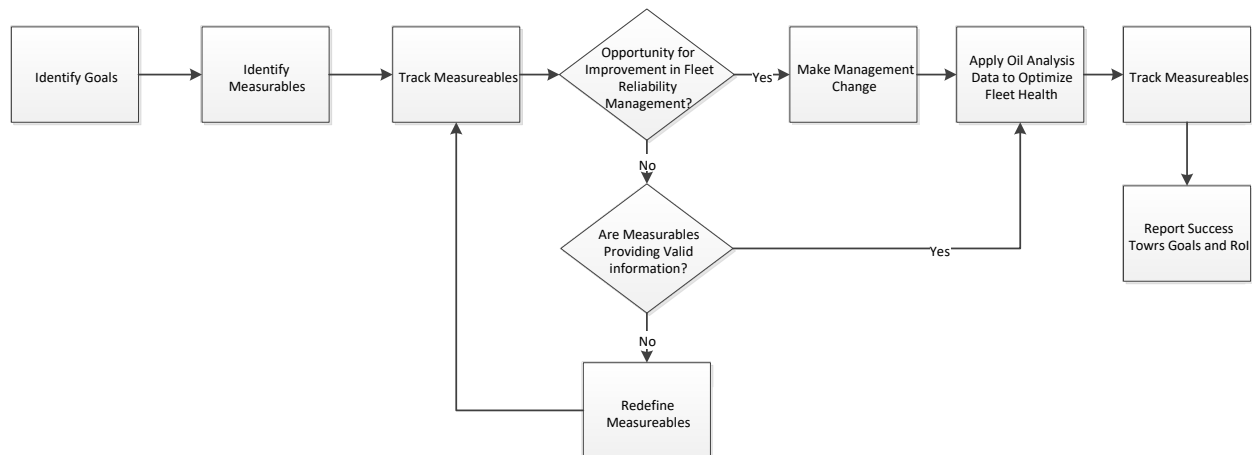
Corrective action includes communicating effectively with the proper personnel and ensures the level of severity is addressed appropriately. Sometimes this is simply arranging to have a second sample sent to the lab for confirmation. Others times it involves ensuring the information is relayed in a timely fashion to the correct personnel. This may include maintenance personnel if equipment reliability is at risk, or lubrication management personnel in order to improve lubrication management or sampling practices.

6.3 Follow Up - Tracking Goals and Return on Investment

Test results and follow up should be monitored for their application to the reliability goals that have been established.

Data collection and management:

- Centralize data collection and reporting
- Document and update measurables identified
- Review defined reporting of laboratory data as it relates to the goals for return on investment
 - Is data collected providing value?
 - What is the overall health of the plant or fleet equipment?
 - Where are the opportunities for improvement in equipment reliability and return on investment?
 - What adjustment should be made in maintenance, equipment, and lubrication management?





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