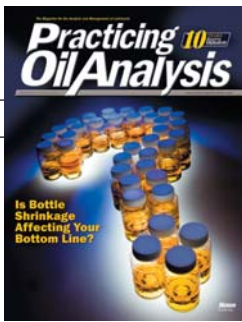


How to Dramatically Increase Throughput and Turnaround

By KEVIN SMITH AND MATTHEW CASSAP, THERMO FISHER SCIENTIFIC



Predictive maintenance is the science of determining how and/or when a piece of equipment will break down. As a result of this, the analysis of used lubrication oil and engine oils for metals is commonplace in many industries such as aerospace, marine, military and heavy machinery.

One of the main benefits of predictive maintenance is the reduction of downtime of a piece of machinery. Another benefit is safety. In the aerospace industry, it is a requirement that engine oil is tested every 250 hours to prevent the failure of a component midflight. The speed at which the results of this analysis are obtained and interpreted is critical. For example, an airplane is often grounded until the results of this analysis are returned with pass criteria.

The challenge for analytical laboratories is to provide an efficient service where

speed of analysis and the interpretation of the results is unparalleled. The dichotomy organizations face is how this speed and coordination are obtained without comprising the quality of the data.

This article considers three primary areas which address these issues: reduction in sample preparation time through automation, speed of sample analysis through the use of advanced instrumentation, and improvement of the overall laboratory workflow through the implementation of a laboratory information management system (LIMS).

The workflow of processing a sample and its associated data for predictive maintenance has numerous steps beyond the obvious ones such as the analysis of the sample and reporting of the data to the customer. While this may vary from lab to lab, a typical end-to-end process is detailed in Figure 1.

Laboratory Automation Reduces Prep Time

Traditional manual sample preparation can be a real bottleneck in a high-throughput/fast-turnaround laboratory typical of those analyzing used lube oils. Samples analyzed by ASTM method D5158 (analysis of wear metals, contaminants and additive elements in used lubrication oils) are required to be diluted by weight by a factor of 10 which typically takes approximately two minutes per sample.

During this sample preparation, sample weights and final weights must be recorded and the dilution factor calculated. The samples are then mixed and transferred to the autosampler racks. The sample preparation for 240 samples (a typical inductively coupled plasma [ICP] analysis) can take up to 10 man-hours (based on dilution time of two minutes, 60 minutes to calculate the dilution factor and 60 minutes to transfer the samples to the autosampler racks).

When the above process is modernized, an auto dilution system such as the APS 1650 from CETAC Technologies (Omaha, Neb.) can be employed to reduce the sample dilution time to around 35 seconds per sample. In such a system, the samples are transferred directly to the autosampler racks, negating the need for a manual transfer. In addition, the auto dilution system is reproducible. Thus, the dilution factor can be assumed to remain constant, negating the need to perform any manual calculations. The total time for sample preparation is now reduced to 2 hours and 20 minutes for the same number of samples.

Modern Instrumentation Increases Throughput

Once the samples are ready to be analyzed, a sample sequence must be created on the ICP by manually entering dilution factors and sample names. Sample analysis is typically around 2.5 minutes per sample with older ICPs. With the required



Figure 2. Spectrometer

standards for calibration and quality control (QC) samples specified by the method, analysis will take approximately 11 hours and 15 minutes (assuming all QC pass and no resamples are required). Final results will then be manually calculated and QC-checked to ensure they meet specifications.

By using a modern ICP such as the Thermo Scientific iCAP 6000 series (Figure 2), the actual sample analysis time can be reduced. This is due primarily to advancements in the design of optical components of the ICPs, which permits a greater amount of light to reach the detector. This allows the analysis time to be reduced while still maintaining the required level of detection.

An additional benefit can be attributed to the reduction in the size of modern instrumentation. Smaller platforms are easier to maintain at a constant temperature, which, in turn, relates to greater stability and less drift. This enhanced stability will be directly translated into more of the QC checks being within limits, resulting in fewer samples being retested.

The net effect of the reduced analysis time and increased stability for the example above is that the analysis time can be reduced to 1.5 minutes per sample, reducing the total analysis time for the 240 samples to 6 hours 45 minutes. Apart from reduced turnaround time, throughput is increased by more than 90 percent, with an additional 219 samples being able to be analyzed in the same time it took to analyze the original 240 samples.

Modern ICPs also have the ability to fully integrate with a comprehensive data management system such as an LIMS by allowing all sample lists to be imported automatically and results to be exported.

Pulling It All Together

Given the higher sample loads in today's process laboratories, lab managers (or users or process scientists) are looking for end-to-end solutions that improve the overall efficiency of the laboratory workflow and ensure quality data is reported to

customers. In the absence of a centralized system, data is often stored in a spreadsheet or multiple spreadsheets. Many of the actions such as the scheduling of samples and transcribing data from the instrument to the spreadsheet for calculations are carried out manually.

Not only is this process slow and time consuming, but it is also prone to human error due to manual actions such as calculations and movement (transcription) and reporting of data. Implementation of quality standards such as ISO 17025 also adds overhead in the running of the laboratory, which also has potential to reduce the overall productivity.

Fortunately, the development of commercial LIMS such as Thermo Scientific SampleManager (Figure 3) has kept pace with such challenges and has the potential to provide significant return on investment. The areas where a LIMS can have significant impact in lube analysis can be summarized in five broad categories: sample scheduling, sample tracking, instrument integration, results management and reporting.

Scheduling

Sample scheduling can bring benefits before the sample has even arrived in the lab, before it has even been collected. Modern LIMS can schedule appropriate

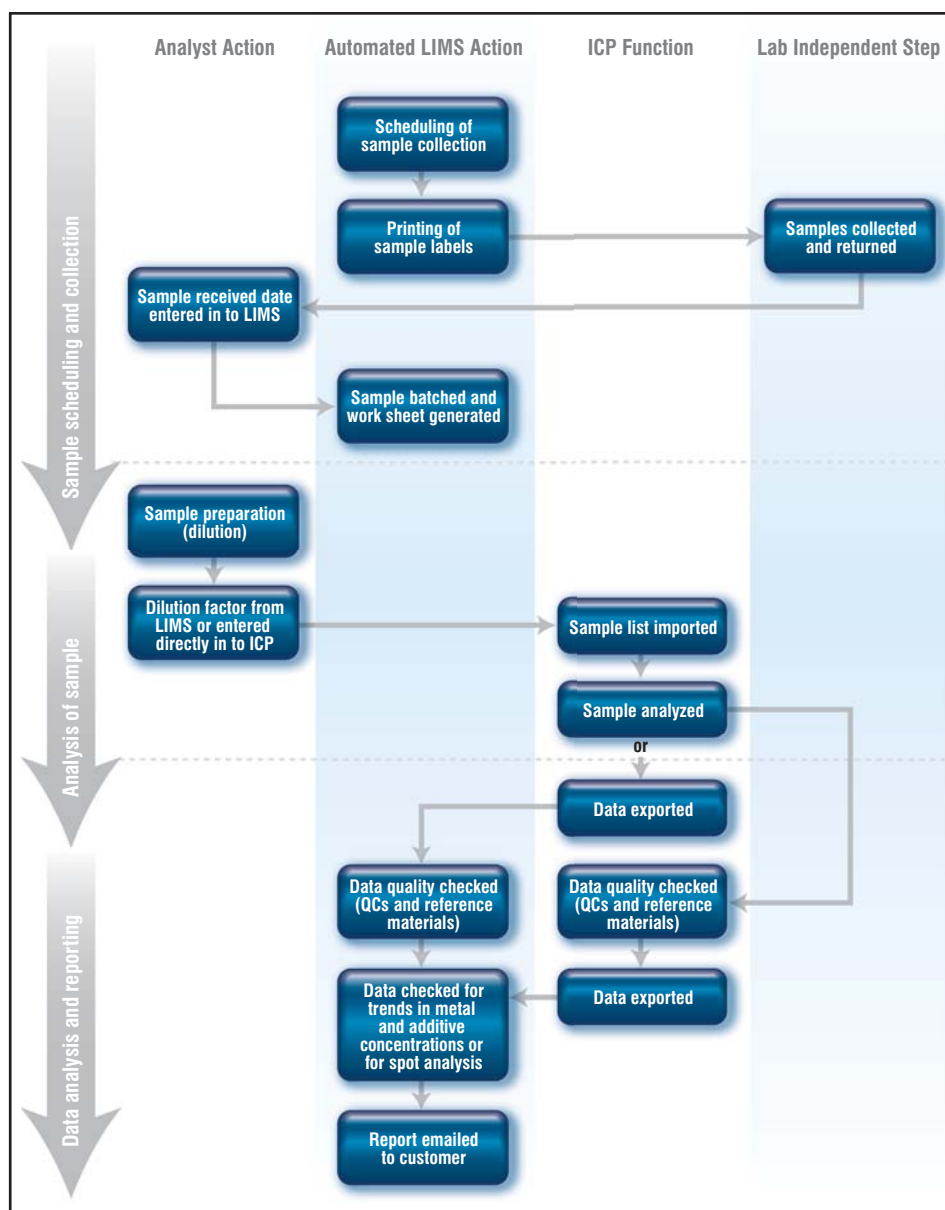


Figure 1. Workflow

samples to be taken either on a timed basis through comprehensive calendar-based scheduling (Figure 1) or driven by an external system such as an enterprise resource planning (ERP) system (SAP being a typical example). Regardless of how the scheduling takes place, the sample collection personnel can be notified by the automatic creation of a collection worksheet detailing samples to be taken, along with barcode labels printed to affix to the sample containers.

Tracking

The next area of operation the LIMS impacts is lube oil sample tracking; in other words, knowing where each sample is at any time. Through the use of barcodes, the LIMS knows when the samples arrive in the lab. It also knows where they are stored prior to lube oil analysis and at what point they are run on the appropriate instrument.

The LIMS can also track and control sample disposal. Implementing sample tracking can speed turnaround time by notifying laboratory staff the second a sample arrives in the lab, as well as reducing the amount of time subsequently spent looking for samples. This in itself can provide significant benefits by ensuring that

when a sample (test) run is set up on an instrument, the maximum number of samples can be analyzed, thereby reducing the laboratory backlog as much as possible.

Instrument Integration

Instrument integration assists in actually running the samples on the instrument. The LIMS can group similar samples for lube oil analysis together in a run list, incorporating dilution factors along with the required blanks and standards according to predefined quality assurance (QA)/QC protocols, as defined by the testing method (for instance ASTM D5158). This is a particularly important area for compliance with ISO 17025, where the LIMS can track which standards were used for a particular sample. This is something for which auditors will often ask to see specific evidence.

Once generated, the runlist can be downloaded to the instrument software. When the run is complete, the results are immediately and automatically uploaded back to the LIMS. This is valuable for lube oil analysis by ICP when there can be many samples with 20 or 30 elements being analyzed simultaneously on each. The time consumed entering and checking the data and potential for tran-

scription errors is minimized or even eliminated when the instruments are tightly integrated with the LIMS.

Results Management

After the results have been captured by the LIMS, additional calculations can be automatically performed to account for dilutions, etc. QA/QC check calculations are then performed automatically to ensure and verify that standards, blanks etc., are within limits. In addition, a critical quality measure in lube analysis is trending of results. These may be checked via Shewhart control charts that are incorporated in LIMS such as SampleManager. Multiple levels of specifications (such as pass, fail and warning) can be stored in the LIMS to be checked and reported automatically. Finally, the results from the ICP can be combined with all other results such as viscosity, flash point or water content for that sample (or batch of samples).

Reporting

The final step in the process is reporting. Without an LIMS, this is usually a piece of paper such as a certificate of analysis (CofA) that is manually compiled with data from various sources. However, with the use of LIMS, the final report or CofA can be automatically generated. An important consideration for compliance with ISO 17025, as well as general good laboratory practice, is the fact that the LIMS is often capable of keeping track of original copies of CofAs, including version numbering.

Once the CofA is finalized, it can be printed. The more common practice, however, is electronic transmission of the results to the customer through either e-mail, a network protocol, or to an ERP for commercial actions (such as invoicing the customer) to be initiated. A common process for the laboratory is to publish the report to a Web server to allow the laboratory's customers to see the results of their sample analysis the moment the final results are reviewed and approved by the laboratory management.



Figure 4. DataManager

Automating this process via a LIMS is a step that can save numerous telephone calls, e-mails and/or faxes to and from the lab and operations for result and progress requests. This frees the lab staff to perform more valuable activities.

Discussion and Conclusions

The benefits of a fully integrated and modern automated sample preparation, advanced instrumentation and a LIMS solution in lube oil analysis are clear. The sample preparation processes are repetitive and, therefore, benefit from automation. The reduced analysis time as well instrument stability gained by investing in a next-generation ICP technology can achieve rapid payback.

Finally, LIMS allows for total optimization of the laboratory process from sample scheduling and tracking to speeding up sample preparation, analysis and reporting. An added benefit is the elimination of manual transcription errors because all data transactions are automated. The LIMS acts as a valuable tool to monitor operations. Such systems highlight any subprocesses that need optimization, as well as help the laboratory to achieve and maintain quality standards such as ISO 17025.

It is essential that LIMS, automated preparation and modern instrumentation are used as an integrated solution to achieve the shortest sample turnaround time and maximum sample throughput, while ensuring the highest standards of data integrity and overall quality. **POA**

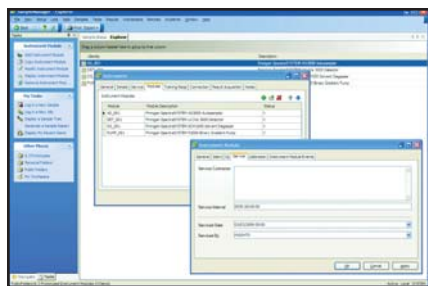


Figure 3. SampleManager



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