

Paper: Integrating Lubrication Management with Lubricant Analysis

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Abstract

In the field of lubrication engineering, the use of software tools has traditionally been broken down into two major areas. The first area contains the tools used to manage the lubrication management process (top ups, greasing routes, oil change intervals etc.). With a couple of notable exceptions, lubricant manufacturers supply these tools to their major customers. The second area contains the tools used to manage lubrication testing and analysis. These software systems are generally supplied by the oil analysis laboratory that conducts the tests, or are part of a suite of condition monitoring systems.

Even in relatively small industrial or transportation organizations, it quickly becomes clear that there is a need for both of these types of systems. If an organization has more than a few hundred lubrication points, using a paper-based system to manage inventory and the scheduling of oiler routes rapidly becomes unwieldy. Similarly, if the organization is using an outside laboratory to test more than twenty or thirty samples a month, electronic data transfer to a software tool becomes preferable to receiving reports through the mail or by fax.

Since different suppliers almost always provide these two systems, you can pretty much guarantee that they do not have the ability to share information, or that there is any method to ensure that the data in the two systems is consistent and correct. Therefore, in solving one set of problems, another problem arises – how to ensure that the two major software tools used in lubrication engineering are kept in lock step with each other?

The other area we are interested in is synergy, the concept that the two systems working together can actually be greater than the sum of their parts. When we are looking at variation in behavior in our lubricant analysis trends, our first question should be “has the oil/grease been altered in any way since the last set of readings”? Being able to query lubrication management data while looking at these trends would be a major advantage. Conversely, when we receive notification from the laboratory of a problem with an oil or class of oils, it is necessary to pinpoint all the machines that use that oil, quickly and easily.

It would seem that bringing lubrication management and lubricant analysis tools closer together might be a good idea. In this paper, we will look in detail at the following areas:

- a) What does a lubrication management system do?
- b) What does a lubricant analysis software package do?
- c) The advantages of an integrated solution for managing lubricant information.

Introduction

In the field of lubrication engineering, the use of software tools has traditionally been broken down into two major areas. The first area contains the tools used to manage the lubrication management process (top ups, greasing routes, oil change intervals etc.). With a couple of notable exceptions, lubricant manufacturers supply these tools to their major customers. The second area contains the tools used to manage lubrication testing and analysis. These software systems are generally supplied by the oil analysis laboratory that conducts the tests, or are part of a suite of condition monitoring systems.

Even in relatively small industrial or transportation organizations, it quickly becomes clear that there is a need for both of these types of systems. If an organization has more than a few hundred lubrication points, using a paper-based system to manage inventory and the scheduling of oiler routes rapidly becomes unwieldy. Similarly, if the organization is using an outside laboratory to test more than twenty or thirty samples a month, electronic data transfer to a software tool becomes preferable to receiving reports through the mail or by fax.

Users of these systems will have noticed that there is considerable overlap between these two types of systems. Lubrication scheduling systems and lubricant analysis systems both require that we enter details about the equipment in our facility or fleet, data about the lubricants we use and where we use them, and scheduling information (either oil management or oil sampling schedules). Both types of systems maintain histories about the lubricants contained in our machines – history of lubricant usage in the lubrication scheduling system, and history of lubricant condition in the lubricant analysis program.

Another thing that users will have noticed is that it has not been possible to have the data in one of the systems trigger an action in the other. Although it is logical that a lubricant analysis result of “dangerously low viscosity” should automatically create a job request to change the oil, this type of automated interaction has not been available.

Finally, the lubricant analyst is handicapped by not having easy access to data in the lubricant scheduling system. The lubrication schedule within the plant, and the types of additions and changes made to the active lubricant within the machine will have a profound effect on lubricant analysis results. Unfortunately, this data is often not readily available to the lubricant analyst. A change to the lubrication schedule (i.e. oil changes, top ups, addition of anti-oxidants or other “sweeteners”) or the operating state of the machine can result in erratic oil trends. These “jumpy” trends seemingly defy explanation – unless the information from the lubricant scheduling program or other condition monitoring data can be viewed at the same time as the lubricant analysis results.

Before jumping into an analysis of what it takes to bring these two types of systems together, let's review what and how these software's work as standalone systems.

Overview of Lubrication Management Systems

The purpose of the lubrication management system is to plan and schedule the deployment of lubrication to oil and grease lubricated machinery. It has been determined that inadequate or improper lubrication accounts for as much as 60% of all mechanical failures in industry. A lubrication management system should ensure that the correct grade of lubricant is delivered to the right place, in the right quantity, at the right time.

Plant Audit of Lubricant Usage

A plant audit of lubricant usage (also known as a lubrication survey or a lubrication chart) is designed to populate the database with a complete set of all oil and grease lubricated equipment in the plant. A database of the oils and greases used in the plant is also required, to ensure that the equipment is linked to its appropriate lubricant. This is the first step in the development of a plant lubrication program. Figure 1 is a typical lubrication report

Create Daily/Weekly/Monthly Lubrication Routes

Once the plant audit has been completed (or while it is being done), the entry of scheduled lubrication tasks is carried out. Each lubrication point on a machine train is identified, linked to its appropriate lubricant and given a lubrication schedule period (i.e. every day, every week, every 5000 miles, every 1500 hours of operation etc.)

Many of the tasks can be gathered together into lubrication routes. A route is a set of lubrication points that are carried out in a sequence. A properly designed route can minimize the amount of time and effort needed to get to all of the lubrication points, and also minimize the amount of lubricant types needed to be used at any one time. This can help ensure that all points are done correctly, and with the correct lubricant.

Generate/Manage Lubrication Schedules

On a periodic basis, the lubrication technician generates those lubrication tasks that are due for the next work period (next day, next week etc.). Any tasks that are overdue have a warning message triggered to remind the technician of incomplete work. The lubrication schedule ensures that lubrication tasks are not forgotten or ignored. Some systems require bar code or memory disk confirmation at the component, to further ensure that the lubrication tasks are being carried out.

Management Reports of Lubricant Application/Usage

There are several types of management reports available from a typical lubrication management system. These reports include lists of overdue lubrication tasks, lists of machines or components that are using an excessive amount, lubricant inventory level reports, etc. Some lubrication systems give you the flexibility of a built-in query engine, which can be used to allow the generation of custom reports.

Equipment ID: 40-04-14-07		Manufacturer: GOULD		Type: Bad Actor Pump			
Equipment: Machine Chest P/P		Model:		Location: 40 Pulp Mill			
Component	Task	Lubricant	Application	Amount	Schedule	Last Done	Batch I
Motor	Grease Bearings	Mobil 1 Synthetic Grease	Grease Gun	3.0 shots	Every Tuesday		Motor Beari
Equipment ID: 40-04-14-01		Manufacturer: GOULD		Type: 40 Pulp Mill			
Equipment: White Water P/P		Model:		Location: 40 Pulp Mill			
Component	Task	Lubricant	Application	Amount	Schedule	Last Done	Batch I
Motor	Grease Bearings	Mobil 1 Synthetic Grease	Grease Gun	3.0 shots	Every Tuesday		Motor Beari
Pump	Level Check and Top Up	Mobil Hydraulic Oil AW 68	Fill Can	0.0 As Needed	Every 30 Days	2/20/2003	Pumps, 40-
Equipment ID: 40-04-14-03		Manufacturer: GOULD		Type: Bad Actor Pump			
Equipment: Machine Chest P/P		Model:		Location: 40 Pulp Mill			
Component	Task	Lubricant	Application	Amount	Schedule	Last Done	Batch I
Motor	Grease Bearings	Mobil 1 Synthetic Grease	Grease Gun	3.0 shots	Every Tuesday		Motor Beari
Pump	Level Check and Top Up	Mobil Hydraulic Oil AW 68	Fill Can	0.0 As Needed	Every 30 Days	2/19/2003	Pumps, 40-
Equipment ID: 40-04-14-04		Manufacturer: GOULD		Type: 40 Pulp Mill			
Equipment: #1 Broke Chest P/P		Model:		Location: 40 Pulp Mill			

Figure 1 – Typical Lubrication Route Report

Overview of Lubricant Analysis Systems

The purpose of the lubricant analysis system is to administer the used oil analysis program. The use of used oil analysis is one of the most effective machine condition monitoring technologies available for both rotating and reciprocating equipment. Lubricant analysis is used to monitor 1) the wear rates of the

machine itself, 2) the level of contaminant particles in the lubricant and 3) the condition of the physical properties of the lubricant.

Laboratories generally offer pre-determined sets of sample tests tailored for specific machine types (i.e. one set of tests for diesel engines, another for compressors, another for gearboxes etc.) In addition to these tests, laboratories offer a wide variety of analytical tests, designed to isolate specific types of problems within the machine or the lubricant.

Software designed for managing oil analysis results (at the client site) must at the very least be able to handle the data produced by the most common types of tests that are carried out by the laboratory. This software is also generally used to retrieve oil analysis data electronically. Electronic administration of lubricant sampling programs is an option offered by most laboratories. Most commercial oil analysis laboratories offer some form of electronic data transfer, allowing you to retrieve the results of your oil sampling via the Internet, either in lieu of or in addition to receiving paper reports.

Some laboratories (and a few commercial software vendors) offer systems that allow the generation of oil bottle labels and other documents required for managing the collection and shipping of oil samples to the laboratory.

The following list details some of the common benefits of lubricant analysis software:

Help To Set Up An Appropriate Lubricant Analysis Test Regimen

Pre-defined test sets within the software package can make it easier to determine the appropriate package of lubricant tests needed for specific machine types (diesel engines, paper machine bearings, compressors etc.).

Generate/Manage Sampling Schedules (Print Labels)

The software can maintain lists (routes) of samples that are to be collected and sent to the laboratory at the same time. Some software can generate the appropriate labels for the laboratory, saving the operator the effort of filling out pre-printed labels by hand.

Acquire and Import Data Electronically from Lab

For most users, the primary reason for using lubricant analysis software is that it is preferable to receive laboratory data electronically instead of receiving paper reports. I think its safe to say that all lubricant analysis software grants some form of electronic access to lab data.

The first access method used by laboratories was built around interfaces to BBS (bulletin board) systems. BBSs' have been replaced by delivery of data by email, or by FTP/HTTP access. Both of these methods can be used to build reliable delivery systems for analysis results.

Acquire/Enter Data From On-Site Oil Instruments

The use of on-site lubricant screening instruments is growing in popularity. These instruments range from simple but useful methods such as patch tests and hotplate water tests to viscometers, contamination/wear particle monitors and lubricant physical properties testers. The results these instruments produce are easier to use when they can be stored in the same database as the results that come from external lubricant analysis laboratories.

Graphs / Tables

The heart of most lubricant analysis software is the data display routines. Most of these packages give you the ability to generate trend graphs and/or data tables showing the results of spectrograph, viscosity, particle count, and TAN/TBN etc. More advanced packages allow you to display non-numeric data such as

analytical ferrography or photomicrography images. Figure 2 shows the type of data displayed by a typical lubricant analysis package.

Manage Rejection Limits (Alarm Levels) for Machines / Lubricants

The end user can maintain a database of machine and/or lubricant alarm levels (rejection limits). These alarms can be used in conjunction with, or as a replacement for, the alarm levels that are used by the testing laboratory. Often users require more rigorous rejection limits than are applied by the laboratory – using a lubricant analysis software is an effective means of receiving notification both when the laboratory detects a rejection limit, and when your lubricant has crossed one of your own limits.

Management Reports of Machinery Condition Based on Lubricant Analysis

The final process for most lubricant analysis systems is the production of management reports. These reports come in two main categories – summary reports that cover the overall condition of many machines (usually all the machines that have recently been analyzed), and detailed reports that show trend graphs, tables of data, and microscope images. These detail reports are nearly always focused on the results of one or more tests that have been carried out on a single sample of oil. Figure 3 shows a typical detail report produced for a single sample.

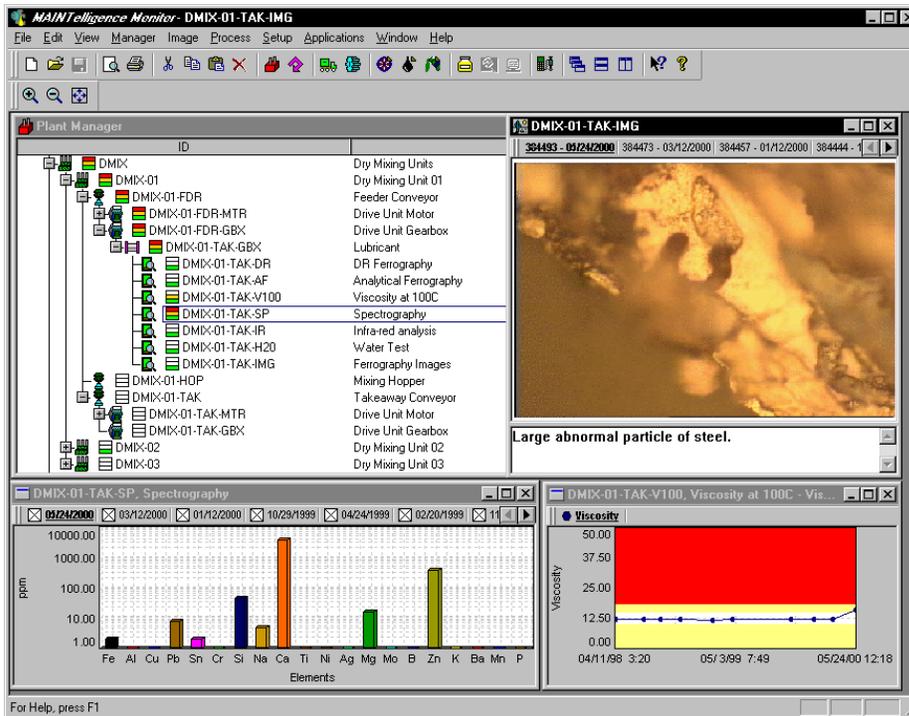


Figure 2 – Lubricant Analysis Data Display

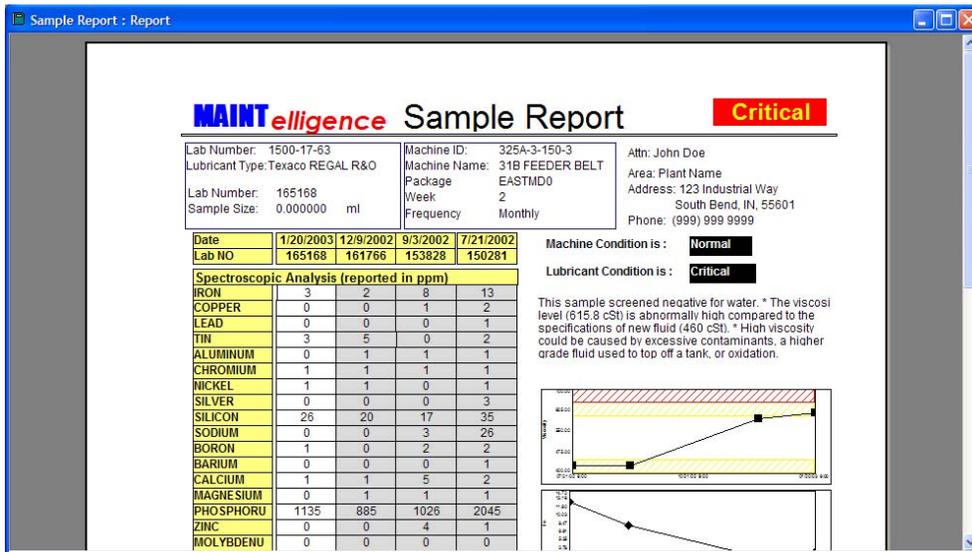


Figure 3 – Sample Report

The Benefit of Tightly Integrated Systems

In the world of software engineering, when two systems have substantial overlap in both data elements and functionality, the solution of choice is a “tightly” integrated system. Tight integration generally implies the ability of the two systems to share data objects (through a common database access method) or to share modules (through a unified object system such as COM or CORBA), or, preferably both. When two systems are built with this tight integration as part of their basic design, some very tangible benefits are generated.

Eliminate Redundant Effort

If you have two separate software packages, one for lubrication scheduling and the other for lubricant analysis, you will have a lot of redundant effort in setup. You will need to enter plant equipment, lubricant master list and supplier information twice. Also, you will need to tailor the structure of this data differently, to match the database requirements of the two systems.

In a tightly integrated system, everything is entered and maintained once.

Insure Information Integrity

With two separate software packages made by different vendors, you can guarantee that they will have (at best) a very limited ability to share information. There will certainly be no methodology to ensure that the data in the two systems is consistent and correct. This means that any change made to the database in the lubrication scheduling system will need to be immediately replicated in the lubricant analysis system, or the two systems will become *inconsistent*. When the data is updated in a tightly integrated system, all shared data elements are kept consistent automatically.

Over the life of the system, automatic information integrity is a feature that produces significant reductions in both effort and cost to the end user, as it eliminates the need to audit the databases of the two systems to ensure that they haven’t drifted apart.

Immediate Access To Information

When information is updated in either the lubricant management part or the lubricant analysis part of the tightly integrated system, the information is immediately available to the users of the other part of the system – for example, when the addition of new oil to a system is registered in the lubricant management part of the system, this information is immediately available to the lubricant analyst attempting to determine the reason for an across-the-board drop on spectrograph readings.

Ability to Automate Actions Across the Two Systems

Whenever companies that use both PM (preventive maintenance) and PdM (predictive maintenance) technologies express an interest in linking the two systems together, the primary requirement is nearly always “to allow the results of the PdM system to automatically flow into the work management system, so that any decision to act on PdM results can take place within the overall maintenance planning structure.” In other words, it is desirable that PdM-generated requests for maintenance show up in the maintenance planner’s PM work schedule just like calendar, operating hour or mileage-based work orders.

This same requirement exists in the lubrication management world. The tightly integrated system is able to take advantage of the common database architecture to allow diagnostics generated by the lubricant analysis system to generate lubrication tasks in the scheduling system. It is not as simple, however, as simply saying, “do this if Fe (Iron) is greater than X ppm”. Effective management of lubricant analysis results either requires a capable automated diagnostic module, or an easy-to-use tool to allow the analyst to enter his or her own condition assessments in a manner that is understandable by an automated system.

An Integrated Solution

Introduction

In this section of the paper, the structure and data flows of the MAINTelligence system will be described. MAINTelligence is a completely integrated CMMS (computerized maintenance management system) and PdM (predictive maintenance) system.

The following sections will concentrate strictly on the structural design issues that make the integration of lubricant analysis data and lubricant management processes possible. The other capabilities and features of MAINTelligence will not be discussed. If you are interested in a more general overview of MAINTelligence as a product, please feel free to contact Design Maintenance Systems Inc. If you use Mobil lubricants, you can also contact your Exxon Mobil lubrication engineer.

MAINTelligence was designed as a modular system, allowing the addition and removal of functionality as needed. Different combinations of MAINTelligence modules are referred to as **configurations**. One configuration of note is Lubrication Management, where the MAINTelligence system is configured strictly as a lubricant analysis / lubricant management system

MAINTelligence was designed from the ground up as a tightly integrated lubricant analysis and lubricant management system. Many of the features included in MAINTelligence were put in specifically to meet the needs of users who would see the system strictly as a lubricant management tool, rather than as a general CMMS solution. One of the major complaints about general CMMS systems is that they lack sufficient flexibility to be applied to the lubrication management function. The goal of the system design for MAINTelligence was to include the necessary functionality needed for effective lubrication management.

System Design

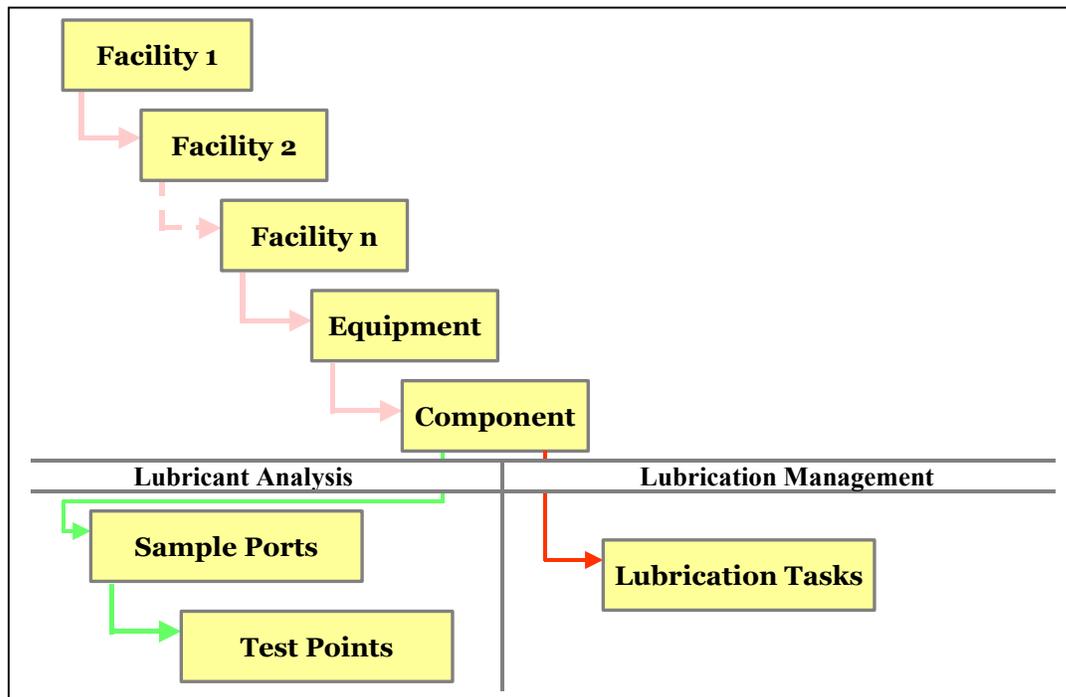
To achieve the goal of having a tightly integrated lubricant analysis and lubrication management system, the primary design issues that needed to be met were as follows:

1. A common plant hierarchy structure, so that the lubricant analyst and the lubricant planner would work on a common database. However, it was important to ensure that the two groups didn’t have

- to be exposed to the details of the others data (unless they wanted such exposure). In other words, a data hiding mechanism was required.
2. Integration of lubrication specification data with lubricant purchasing / inventory data. Lubrication specification data tends to be entered into a system at startup and then allowed to go stale (data is not continuously updated). By linking specification data to the much more active inventory management data, we felt that this would help ensure that lubrication specification data is kept up-to-date.
 3. Allow data collected in the lubricant analysis database to be used to trigger lubrication tasks. However, we wanted the system to do it intelligently, rather than simply generating a lubrication task based on simple alarms. An easy-to-use but powerful condition assessment capability was required.
 4. Allow data collected in the lubricant analysis database to be used both for tracking condition of the lubricant and usage/operation of the equipment. In other words, allow meter data to be collected and stored along with laboratory analysis results. Also, we wanted that meter data to be able to trigger lubrication tasks along with the condition data.
 5. Allow data collected by on-site instruments to be matched with the data generated by laboratories, allowing both data sets to be used together to manage lubrication tasks.
 6. Design the system so that multiple lubrication tasks could be issued to multiple lubrication technicians from a single screen, or to send those tasks to a lubrication technician's handheld work management device.
 7. Make the management of scheduled lubrication tasks to be as simple as possible. Allow the lubrication planner to close off multiple lubrication tasks from a single screen, preferably with a single button.

System Structure

The structure of the system's database is a hierarchy that reflects the plant equipment breakdown chart. There can be as many levels of **facility** as required (a facility can be a building, a geographical area, a ship, a hydraulic system etc.) **Equipment** is defined as machine trains or driver-driven combinations (motor-pump, diesel-generators, turbo-compressors) broken down into their individual **components**.



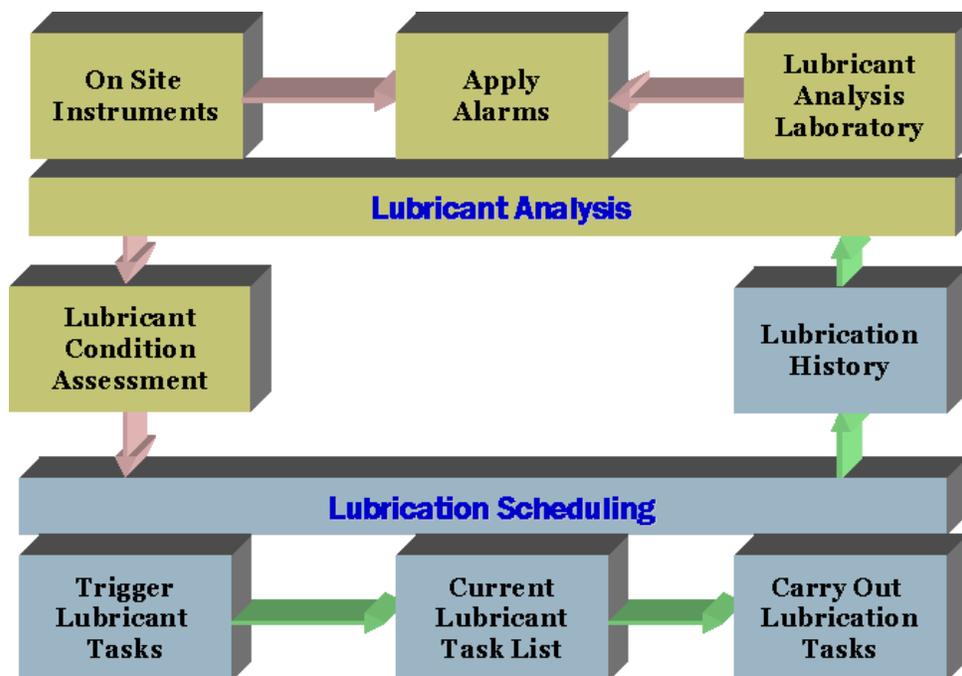
Below the component level, the system hierarchy separates. Both the lubricant analyst and the lubrication planner are able to see the common plant structure. However, when the analyst opens the plant hierarchy tree to the bottom, he sees a list of sample ports and the various tests (spectrography, viscosity, FTIR etc.) that are applied to samples taken from a sample port. The planner, on the other hand, sees a list of lubrication tasks that are to be applied to that motor, pump, gearbox etc., and their associated schedules. The different views are part of the “data hiding” principle – don’t show people the detail that they are not interested in.

With this system structure, the system is able to “know” that a test point under a specific component can be associated with one or more lubrication tasks on that same component. The stage is set to allow data contained in that test point to alter the schedule for on a lubrication task.

Our development efforts have convinced us that the common plant structure is the key element in determining the success or failure of maintenance management integration efforts. Without the common plant structure, the effort involved to build and configure “glue” components (both programmatically and by plant engineers) becomes so high that the level of effort may be deemed to be greater than the benefit of the integration. The common plant structure reduces the effort to a feasible level.

System Dataflow

The dataflow of a system describes the steps undertaken by the system to move data from one module to the next. There are several key dataflow steps required to ensure a smooth interface between lubricant analysis and lubrication management.



Lubricant Analysis Module

1. *Collect data*

The data collection process for lubricant analysis involves one of the following:

1. Direct data acquisition from an on-site instrument;
2. Retrieving data from an oil analysis laboratory, either through a web site, an FTP site or email;

3. Downloading data from a PDA-like device used for field inspections;
4. Manual data entry.

2. *Apply alarms*

During the data collection process, preset alarm levels are applied to determine if any of the data being put into the lubricant analysis database crosses an alarm threshold.

3. *Generate Lubricant Condition Assessment*

An inference engine collectively analyzes all symptoms for a particular component or equipment level object. The inference engine can use all of the data contained within the symptom objects to generate one or more diagnostics for the oil sample or inspection route.

Lubrication Scheduling Module

4. *Trigger Lubricant Tasks*

The lubricant planner is able at any time to update his job backlog by running a “Trigger Tasks” process. This process compares all the tasks in the database to their schedule, and generates them as scheduled tasks if they are due.

The same process also checks for any new condition assessment diagnostics or meter data that may have been added since the last job generation. These new assessments are matched to any tasks that are triggered by the condition of the oil. If the oil condition matches the condition trigger for the task, the task is then scheduled, exactly in the same manner as if it were a calendar or meter-based task.

5. *Carry Out Lubrication Tasks*

The planner is given final control over which jobs get approved and submitted to the lubrication technicians. The approved jobs are given a work order number, and can be delivered to the technician as a work order list, a series of printed work order forms or electronically as email or downloaded to a PDA.

The full lubrication task specifies the operation to be carried out, the type of lubricant to use, and (sometimes) how much to use.

6. *Create Lubrication History*

Once the lubrication task has been carried out, the job is closed. The closing procedure has the lubrication technician enter the actual type and amount of lubricant used, which can be compared to the budgeted amount. All data is ported to history, where it can be used to analyze weekly, monthly, annual lubricant consumption and other costs of operation.

Condition Assessments as Lubrication Task Triggers

There are several issues with using alarms only as the triggering mechanism for lubrication tasks. For example, say there is a lubrication task that is triggered by a simple alarm such as high iron, and there is a second, more important task that is triggered by high iron, high silicon and a decreasing viscosity trend. If tasks are triggered simply by alarms, how do you specify the trigger for the second task? And how do you make sure that the second task gets generated, but that the first task doesn't?

The use of a simple set of rules (and an associated inference engine) increases the effectiveness of using oil analysis data as a trigger for lubrication tasks. Without the filtering capability of a rule base, the user could potentially be overwhelmed by spurious or conflicting lubrication tasks.

Cross-Module Data Access

The data hiding mechanism prevents the lubrication planner or lubricant analyst from being overwhelmed by data that is not immediately relevant or desired. However, the lubricant analyst is likely to be very interested in the lubrication history for a component that is showing signs of lubricant-related failure. The lubricant analyst should be able to see specific data sets from the lubrication management system while being shielded from all the other task detail. Conversely, the lubrication management system user should be able to see condition assessment results without getting bogged down in all of the lubricant test data.

Conclusion

There are some substantial benefits in integrating lubrication management and lubricant analysis tools. The conclusions that we have reached in developing and implementing such an integrated system are:

1. The use of a common plant hierarchy is an essential step in ensuring that the benefits of integration are not overwhelmed by implementation complexity.
2. The effort involved in setting up a tightly integrated system is more than setting up an individual lubricant analysis or lubrication management database, but it is considerably less than setting up both systems independently. However, the real benefit (regarding labor requirements) is that the tightly integrated system requires considerable less maintenance over the long haul, as there aren't multiple databases that can get out of sync.
3. Using a rule-based interface layer (even a very simple one) between lubricant analysis data and lubricant task triggers prevents a lot of unnecessary lubrication task generation, and helps to prevent the generation of conflicting tasks.
4. Both parts of the integrated system need to hide detail from the other, but certain data sets need to be viewable across the system.